

Fishery Data Series No. 99-35

Stock Status of Chena River Arctic Grayling in 1998

by
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November 1999

Alaska Department of Fish and Game

Division of Sport Fish



Symbols and Abbreviations

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Weights and measures (metric)		General		Mathematics, statistics, fisheries	
centimeter	cm	All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.	alternate hypothesis	H _A
deciliter	dL	All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.	base of natural logarithm	e
gram	g	and	&	catch per unit effort	CPUE
hectare	ha	at	@	coefficient of variation	CV
kilogram	kg	Compass directions:		common test statistics	F, t, χ^2 , etc.
kilometer	km	east	E	confidence interval	C.I.
liter	L	north	N	correlation coefficient	R (multiple)
meter	m	south	S	correlation coefficient	r (simple)
metric ton	mt	west	W	covariance	cov
milliliter	ml	Copyright	©	degree (angular or temperature)	°
millimeter	mm	Corporate suffixes:		degrees of freedom	df
Weights and measures (English)		Company	Co.	divided by	÷ or / (in equations)
cubic feet per second	ft ³ /s	Corporation	Corp.	equals	=
foot	ft	Incorporated	Inc.	expected value	E
gallon	gal	Limited	Ltd.	fork length	FL
inch	in	et alii (and other people)	et al.	greater than	>
mile	mi	et cetera (and so forth)	etc.	greater than or equal to	≥
ounce	oz	exempli gratia (for example)	e.g.,	harvest per unit effort	HPUE
pound	lb	id est (that is)	i.e.,	less than	<
quart	qt	latitude or longitude	lat. or long.	less than or equal to	≤
yard	yd	monetary symbols (U.S.)	\$, ¢	logarithm (natural)	ln
Spell out acre and ton.		months (tables and figures): first three letters	Jan,...,Dec	logarithm (base 10)	log
Time and temperature		number (before a number)	# (e.g., #10)	logarithm (specify base)	log ₂ , etc.
day	d	pounds (after a number)	# (e.g., 10#)	mideye-to-fork	MEF
degrees Celsius	°C	registered trademark	®	minute (angular)	'
degrees Fahrenheit	°F	trademark	™	multiplied by	x
hour (spell out for 24-hour clock)	h	United States (adjective)	U.S.	not significant	NS
minute	min	United States of America (noun)	USA	null hypothesis	H ₀
second	s	U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)	percent	%
Spell out year, month, and week.				probability	P
Physics and chemistry				probability of a type I error (rejection of the null hypothesis when true)	α
all atomic symbols				probability of a type II error (acceptance of the null hypothesis when false)	β
alternating current	AC			second (angular)	"
ampere	A			standard deviation	SD
calorie	cal			standard error	SE
direct current	DC			standard length	SL
hertz	Hz			total length	TL
horsepower	hp			variance	Var
hydrogen ion activity	pH				
parts per million	ppm				
parts per thousand	ppt, ‰				
volts	V				
watts	W				

FISHERY DATA SERIES NO. 99-35

**STOCK STATUS OF CHENA RIVER
ARCTIC GRAYLING IN 1998**

by

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November 1999

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ABSTRACT

Status of the Arctic grayling *Thymallus arcticus* stock in the lower 144 km of the Chena River in 1998 was described by estimates of abundance, age and length composition, recruitment, and survival rate estimates during July. Estimated abundance was 27,563 (SE = 3,604) Arctic grayling ≥ 150 mm FL. Ages 1 through 13 were represented in the sample of which the largest percentage was age-5 at 25%. Stock-size (150 - 269 mm FL) and quality-size Arctic grayling (270 - 339 mm FL) each comprised 48% of the population. Recruitment of age-5 fish between 1997 and 1998 was 6,830 (SE = 1,050) Arctic grayling and annual survival during this period was 90.5% (SE = 11.0%). A comparison of the catches between May and July sampling showed a significantly higher proportion of large adult sized fish in May. In addition, the catch of the two samples when judged by effort suggested greater abundance of fish in May.

Key words: Arctic grayling, *Thymallus arcticus*, electrofishing, population abundance, composition, Relative Stock Density, recruitment, survival rate, Chena River.

INTRODUCTION

BACKGROUND

The Chena River is a clear-water tributary to the Tanana River originating in the Tanana Uplands 144 km east of Fairbanks. The river flows approximately 252 km from the uppermost reach in the East (Middle) Fork to the confluence with the Tanana River at Fairbanks. The river drains a watershed of 5,130 km² and includes five major tributaries: North Fork, West Fork, South Fork, East (Middle) Fork, and the Little Chena River (Figure 1). Collectively, these major tributaries and the mainstem are over 470 km in length. Urban development is extensive along the lower 40 km of the river, and road accessibility extends along a majority of the lower 183 km.

The Chena River provides habitat for at least 14 fish species: Arctic grayling *Thymallus arcticus*, chinook salmon *Oncorhynchus tshawytscha*, chum salmon *O. keta*, round whitefish *Prosopium cylindraceum*, slimy sculpin *Cottus cognatus*, burbot *Lota lota*, longnose sucker *Catostomus catostomus*, Arctic lamprey *Lampetra japonica*, northern pike *Esox lucius*, sheefish *Stenodus leucichthys*, humpback whitefish *Coregonus pidschian*, broad whitefish *C. nasus*, least cisco *C. sardinella* and lake chub *Couesius plumbeus*. The latter six species prefer the lower half of the river while the former eight the entire river. Recreational fisheries occur on nine of the 14 species (total catch in 1997 is in parenthesis; Howe et al. 1998): Arctic grayling (72,344), salmon sp. (3,446), northern pike (1,762), burbot (735), and whitefish sp. (442).

Due to its proximity to Fairbanks and road accessibility, the Chena River supports the largest Arctic grayling fishery in North America. The status and character of the fishery however, has changed dramatically since 1985. From 1977 through 1984, the annual harvest of Arctic grayling averaged 30,000 fish and annual angling effort for all species averaged 34,000 angler days (Mills 1979-1985; Table 1; Figure 2). For 1985 and 1986, average harvest declined dramatically to 7,000 Arctic grayling while effort decreased to 24,500 angler days (Mills 1986-1987; Table 1; Figure 2). Concomitant with the rapid decline in harvest was a decline in abundance. Stock assessment projects during 1986 (Clark and Ridder 1987) and 1987 (Clark and Ridder 1988) indicated a decline in population abundance near 50% between these two years. The sudden declines in the fishery and population prompted fishery managers to process

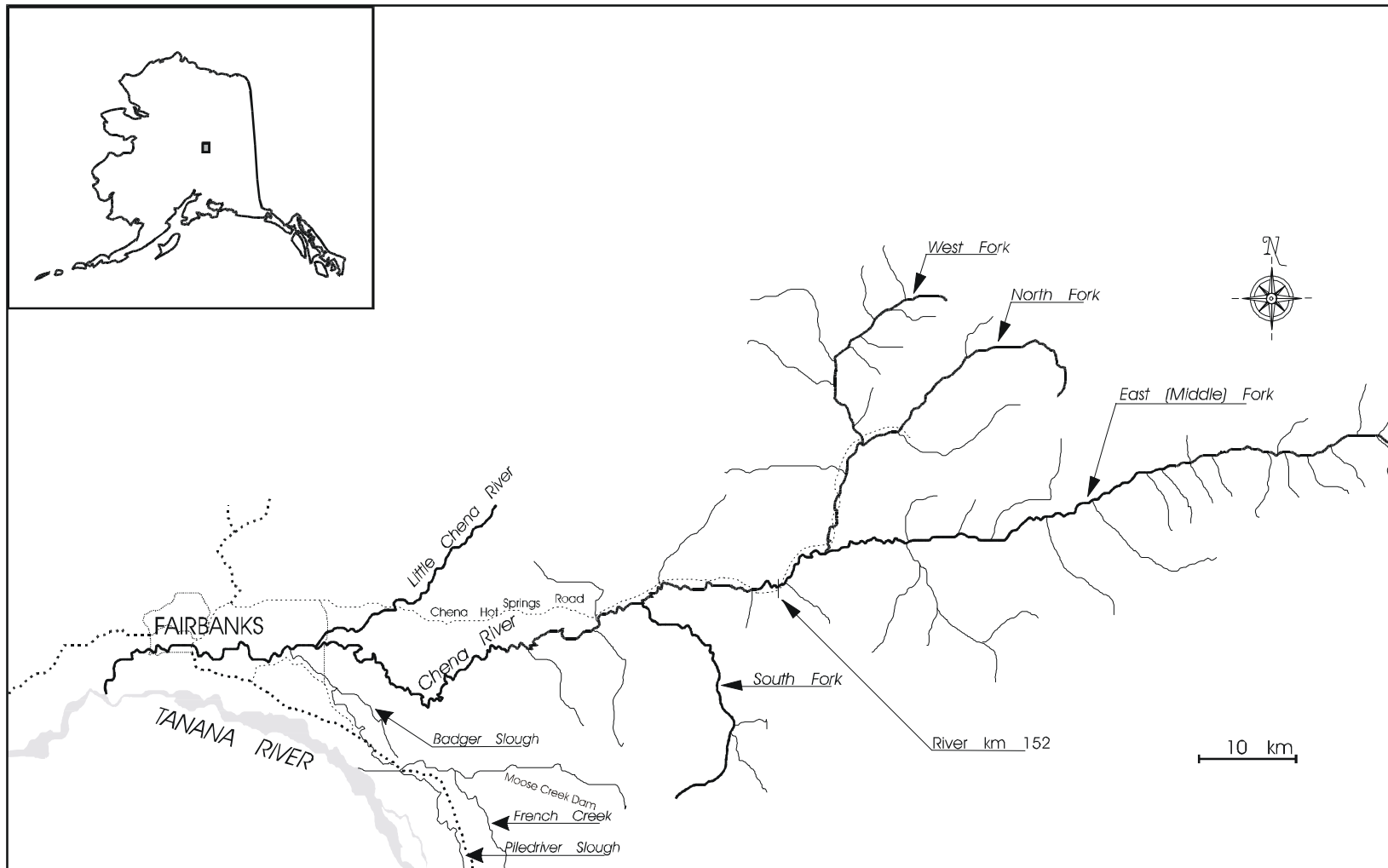


Figure 1.-The Chena River drainage.

Table 1.-Angling effort, harvest, and catch of Arctic grayling from the Chena River, 1977-1997 (Mills 1979-1994 and Howe et al. 1995-1998).

Year	Lower Chena River ^a			Upper Chena River ^b			Entire Chena River		
	Angler-Days ^c	Harvest	Catch	Angler-Days	Harvest	Catch	Angler-Days ^c	Harvest	Catch
1977	---	---	---	---	---	---	30,003	21,723	---
1978	---	---	---	---	---	---	38,341	33,330	---
1979	9,430	11,290	---	8,016	11,664	---	17,446	22,954	---
1980	13,850	18,520	---	10,734	16,588	---	24,584	35,108	---
1981	11,763	10,814	---	10,740	13,735	---	22,503	24,549	---
1982	18,818	11,117	---	15,166	12,907	---	33,984	24,024	---
1983	17,568	7,894	---	16,725	10,835	---	34,293	18,729	---
1984	20,556	13,850	---	11,741	12,630	---	32,297	26,480	---
1985	11,169	2,923	---	8,568	3,317	---	19,737	6,240	---
1986	18,669	4,167	---	10,688	3,695	---	29,357	7,862	---
1987 ^d	12,605	1,230	---	10,667	1,451	---	23,727	2,681	---
1988 ^{d,e}	16,244	2,686	---	9,677	1,896	---	25,921	4,582	---
1989 ^{d,e}	20,317	7,194	---	10,014	5,441	---	30,331	12,635	---
1990 ^{d,e,f}	18,957	3,494	22,062	6,949	945	10,769	25,906	4,439	32,831
1991 ^{d,e,f,g}	12,547	2,997	14,860	8,591	722	14,688	21,138	3,719	29,548
1992 ^h	7,671	0	11,270	4,983	0	9,039	12,654	0	20,309
1993 ^h	15,631	0	26,805	6,018	0	17,173	21,649	0	43,978
1994 ^h	18,718	33	32,759	7,912	82	27,193	26,630	115	59,952
1995 ^h	23,219	0	15,181	13,319	212	23,428	36,538	212	38,609
1996 ^h	30,714	0	23,278	15,228	0	26,805	45,942	0	50,083
1997 ^h	22,800	0	28,796	14,838	0	42,572	37,638	0	71,368
Average	16,987	---	21,876	10,557	---	21,458	31,100	---	43,715

-continued-

Table 1.-Page 2 of 2.

- ^a Lower Chena River, as defined by the Statewide Harvest Survey, is from the mouth upstream to 40 km Chena Hot Springs Road (Mills 1988) or approximately river km 114. For 1991 through 1996 the Lower Chena River included Badger Slough. Angling effort is for all species of fish.
- ^b Upper Chena River, as defined by the Statewide Harvest Survey, is the Chena River and tributaries accessed from the Chena Hot Springs Road beyond 40 km on the road (Mills 1988) or approximately river km 114. Angling effort is for Arctic grayling.
- ^c Angler-days and harvest included Badger Slough. Angler days is effort for all species.
- ^d Special regulations were in effect during 1987 through 1991. These regulations were: catch-and-release fishing from 1 April until the first Saturday in June; a 305 mm (12 inch) minimum length limit; and, a restriction of terminal gear to unbaited artificial lures.
- ^e In addition to the special regulations, a catch-and-release area was created on the Upper Chena River (river kilometer 140.8 to 123.2).
- ^f The daily bag and possession limits were reduced from five fish to two fish in 1990.
- ^g During 1991, the Chena River and its tributaries were closed to possession of Arctic grayling from 1 July through 31 December.
- ^h During 1992 through 1997, the Chena River and its tributaries were closed to possession of Arctic grayling from 1 January through 31 December.

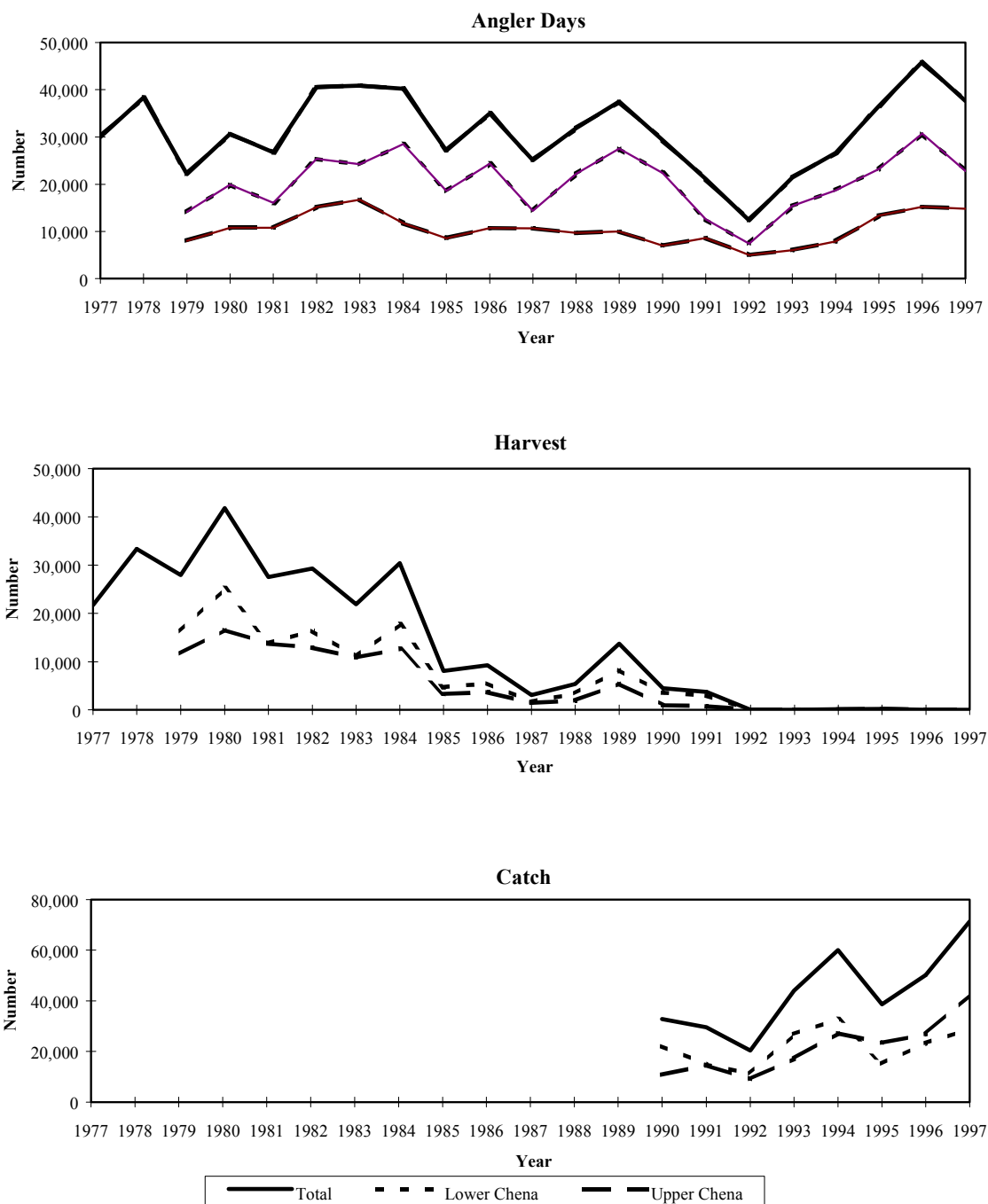


Figure 2.-Annual effort (angler days), harvest, and catch of Arctic grayling in the Chena River 1979-1997 (Mills 1979-1994 and Howe et al. 1995-1998).

emergency regulations for the 1987 season to reduce harvest. The emergency regulations that were adopted or amended by the Alaska Board of Fisheries (BOF) were:

1. catch-and-release fishing from 1 April to the first Saturday in June;
2. a 12-inch (305 mm) minimum total length limit from the first Saturday in June until 31 March;
3. restriction of terminal gear to unbaited artificial lures throughout the Chena River except downstream of the Moose Creek Dam where bait fishing is allowed only with hooks having a gap larger than 0.75 inch (19 mm);
4. only catch-and-release fishing from river kilometer 140.8 downstream to river kilometer 123.2; and,
5. a reduction in possession limit from 10 to 5 fish (Tanana River drainage-wide regulation).

These regulations were the first changes in Arctic grayling management since 1975 at which time the daily bag limit was decreased from 10 to 5 fish.

By 1990, annual estimates of abundance suggested these new regulations were not effective in increasing the population. This prompted the BOF to implement a daily bag limit of two fish drainage wide and adopt single hook regulations upstream of the Moose Creek Dam. On 1 July 1991, fishery managers issued an emergency order and reduced the daily bag limit to 0 fish throughout the Chena River drainage. This emergency order remained in effect through 1994. In 1994, the BOF passed a regulation to keep the daily bag limit at 0 fish through 1997. In 1997, the BOF retained this regulation through 2000.

Since the imposition of a zero bag limit, estimated abundance of Arctic grayling greater than \geq 150 mm FL has cycled from 26,800 fish in 1991 to a high of 45,100 fish in 1995 then down to 35,800 in 1997. However, estimated abundance of fish age-5 and older has increased from a low of 7,900 fish in 1991 to an average of 14,100 fish between 1992 and 1997 (from 10,400 to 19,700 fish yearly). Catch and effort of the fishery has been trending upward. Estimated angling effort (all species) has increased from 12,654 angler days in 1992 to a high of 45,942 angler days in 1996 while catch of Arctic grayling has increased from 29,548 fish in 1991 to 71,368 in 1997 (Table 1).

Along with regulation changes to ensure adequate protection of the stock, a stocking program occurred in 1993 and 1994 to see if the release of hatchery and pond-reared Arctic grayling could supplement the natural production. Using brood stock from the Chena River and rearing at Clear Hatchery, 64,936 age-1 fish (1992 year class) were stocked into the river in 1993 and 61,435 age-1 fish (1993 year class) in 1994. Stocked fish made up 45% of the population in 1993 and 51% in 1994 (Clark 1994 and 1995) and, with an average size of 210-mm FL at stocking, could have provided for a limited consumptive fishery. The stockings, however, were not considered successful in the long term due to high mortality and/or emigration one year after stocking that resulted in a loss of approximately 95% of each cohort. In 1997, stocked fish made up less than 1% of the assessed population and 9% to 2% of the 1992 and 1993 year classes, respectively (Ridder 1998).

The lower 144-km of the Chena River has been the site of stock assessments since the late 1960s. The area comprises approximately 70% of the fished portion of the drainage but, at most, only 36% of the drainage's length (approximately 400 km of major tributaries and mainstem). Arctic grayling inhabit the entire drainage (Tack 1980) and exhibit annual movements between wintering, spawning, and summer feeding areas (Northcote 1995).

It is important to qualify the assessed population of Arctic grayling in the Chena River as it relates to the entire population. Investigators believe that Arctic grayling of the Chena River behave similar to Arctic grayling of the Goodpaster River. Recent research in the lower 52 km of the Goodpaster River has shown that composition of Arctic grayling during spring spawning was significantly different than that found during summer (Ridder 1998b). Estimated abundance of adult fish (fish ≥ 270 mm) within the Goodpaster River during spawning was 80% - 90% greater than the number of adults present in summer. If Arctic grayling from the Chena River behave similar to the fish from the Goodpaster River, the number of fish in the lower Chena River would be greater and the length composition larger during the spring than during the summer.

Tack (1980) hypothesized that Arctic grayling seek out the warmest portions of a drainage for spawning to provide maximal growth for their progeny. In the clear water tributaries of the Tanana drainage, this is usually in the lower reaches of the river. In 1995, 86% of adult fish in the lower 112 km of the Goodpaster River spawned in the lower 52 km (Ridder 1998b). Even though Arctic grayling have been found to spawn throughout the Goodpaster and Chena rivers (Tack 1980; Ridder 1998), the greatest production is probably in the lower reaches. Knowledge of seasonal distributions, movements, and abundance of the population would enhance the understanding of the Chena River Arctic grayling population.

OBJECTIVES FOR STOCK ASSESSMENT

To accurately and precisely describe the status of the Arctic grayling stock in the Chena River, the 1998 objectives (R-3-2a) were to:

1. estimate the July abundance of Arctic grayling (≥ 150 mm FL) in the lower 144 km of the Chena River;
2. estimate the July age composition of Arctic grayling (≥ 150 mm FL) in the lower 144 km of the Chena River;
3. estimate the July length composition of Arctic grayling (≥ 150 mm FL) in the lower 144 km of the Chena River; and,
4. test the hypothesis that the length distribution of Arctic grayling (≥ 150 mm FL) in the lower 144 km of the Chena River in May was the same as in July.

In addition to these primary objectives tasks were to determine the spatial distribution of adult Arctic grayling in the spring immediately following ice-out in the lower 144 km of the Chena River, mark all Arctic grayling captured in May with individually numbered anchor tags; and, observe recapture locations of May-tagged fish during the July assessment.

METHODS

Based on differences in capture probability from downstream to upstream areas of the Chena River, the 144 km study area is divided into two sections at the Moose Creek Dam complex.

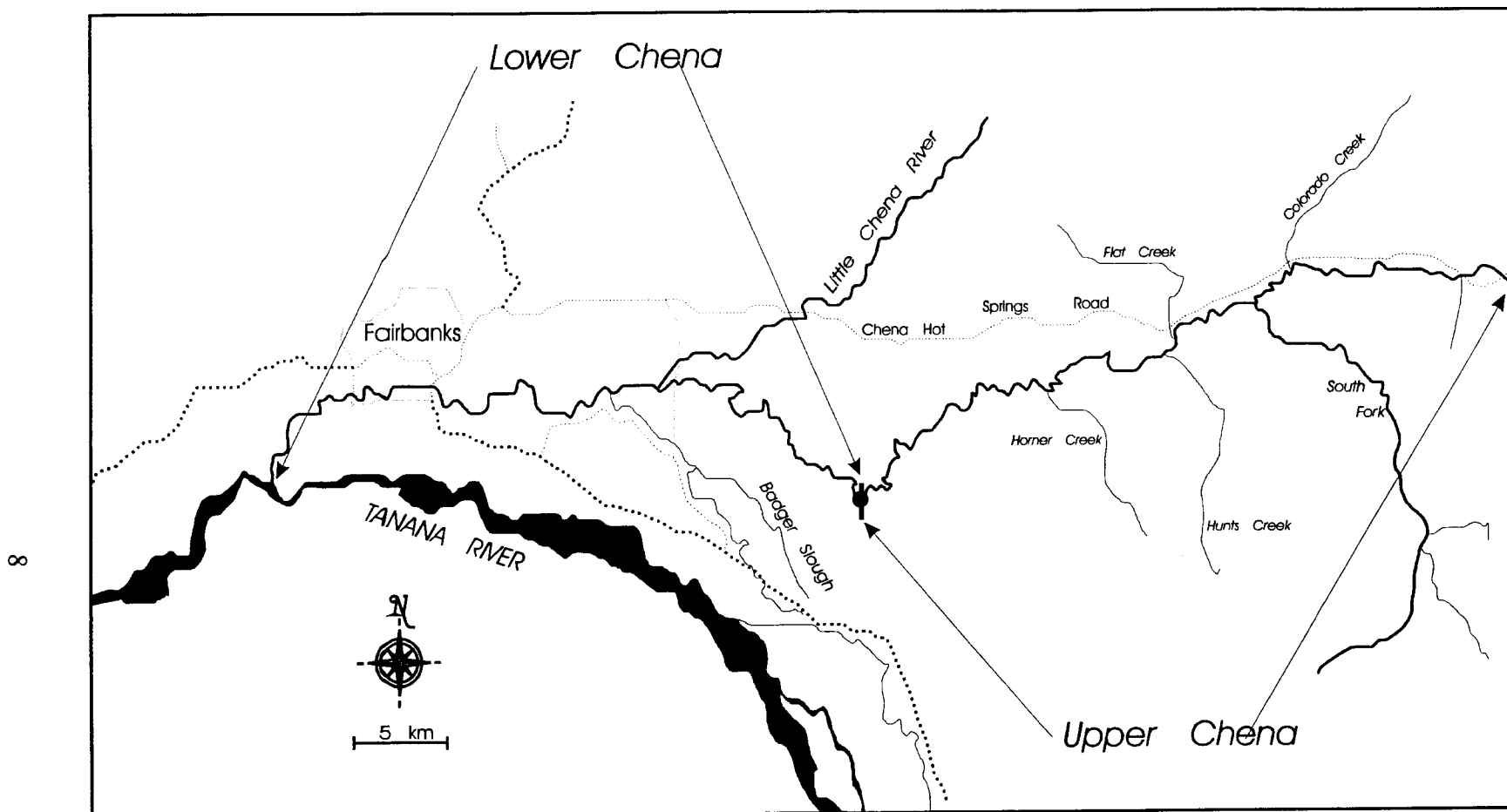


Figure 3.-Stock assessment sections in 1998 along the lower 144 km of the Chena River drainage.

Downstream from the dam to river kilometer 8 of the Chena River was designated the lower section (64-km long; Figure 3). Upstream from the dam to the first bridge on the Chena Hot Springs Road (km 62.4) was designated the upper section (80-km long; Figure 3). Population abundance estimates pertain only to these two sections of the Chena River. Arctic grayling inhabiting Badger Slough, the Little Chena River, and the South, West, North, and East forks of the Chena River at the time of this experiment are not included in the estimates.

SAMPLING GEAR AND TECHNIQUES

During 1998, all fish were captured using pulsed-DC (direct current) electrofishing systems mounted on 6.1-m-long river boats as previously described by Lorenz (1984). Input voltage (240 VAC) was provided by a 3,500 or 3,800 W single-phase gas powered generator. A variable voltage pulsator (Coffelt Manufacturing Model VVP-15¹) was used to generate output current. Anodes were constructed of 16.0 mm diameter and 1.5 m long twisted steel cable. Four anodes were connected to the front of a 3-m-long “T-boom” attached to a platform at the bow of the boat. The aluminum hull of the river boat was used as the cathode. Output voltages during sampling varied from 200 to 300 VDC and amperage from 2.5 to 4.0 A. Duty cycle was 50% and pulse rate was 60 Hz. Sampling was conducted along the banks of the Chena River in 20-min intervals (≈ 1.6 km). In the lower section, two electrofishing boats were each directed downstream simultaneously along each bank, capturing all Arctic grayling. In the upper section, one electrofishing boat was directed downstream selectively fishing one bank or the other. Due to the upper section’s narrow width and frequent meanders, preferred Arctic grayling habitat is seldom along both banks. Captured Arctic grayling were held in an aerated holding tub for sampling at the end of each sampling interval or “run”. The two river sections were sampled once per day to prevent changes in the capture probability of marked fish compared to unmarked fish due to multiple exposure to the gear (Cross and Stott 1975). Each Arctic grayling was measured to the nearest 1-mm FL. During the second event of the mark-recapture experiment, a sample of scales was taken approximately six-scale rows above the lateral line and just posterior to the insertion of the dorsal fin of each wild Arctic grayling. In the lower section, Arctic grayling ≥ 150 mm FL were marked with a partial right-pectoral clip in the first event and a partial upper-caudal clip in the second event. In the Upper Chena section, Arctic grayling ≥ 150 mm FL were marked with a partial left-pectoral clip in the first event and a partial lower-caudal clip in the second event. All enhancement fish (hatchery and pond-reared releases) were identified with a complete fin clip (complete left or right ventral for hatchery and adipose for pond-reared releases) given prior to stocking. If any captured Arctic grayling exhibited signs of injury or imminent mortality, they were immediately released and recorded as killed on data collection forms.

ESTIMATION OF ABUNDANCE

Abundance of Arctic grayling ≥ 150 mm FL was estimated with the modified Petersen estimator of Bailey (1951, 1952). Marking of fish in each study section required four days, sampling four areas within a section. For any one area there was a hiatus of seven days between events. Sampling during the second event was the same as in the first event. Sampling the upper and lower sections was conducted concurrently from 6 through 16 July 1998.

The assumptions necessary to accurately estimate abundance in this population were that (Seber 1982):

¹ Product names used in this publication are included for scientific completeness but do not constitute product endorsement.

1. the population was closed (no change in the number or composition of Arctic grayling in the population during the experiment);
2. all Arctic grayling had the same probability of capture in the first sample or in the second sample, or marked and unmarked Arctic grayling mixed uniformly between the first and second samples;
3. marking of Arctic grayling did not affect their probability of capture in the second sample;
4. Arctic grayling did not lose their mark between sampling events; and,
5. all marked Arctic grayling are reported when recovered in the second sample.

Testing of Assumptions

Assumption 1 was implicitly assumed since the large size of the sections (64 and 80 km) and short duration of the experiments (two weeks) reduced the probability of fish leaving the sections during the experiment. In addition, the short duration reduced the likelihood that mortality or recruitment due to growth would occur between sampling events.

Assumptions 2 and 3 were tested in regards to area and length of fish. To determine if capture probability differed between areas, each river section was first divided into four equal areas. The recapture-to-catch ratios of each area were compared using a chi-squared contingency table (Seber 1982). In the case that this test was not significant, one of the “or” assumptions of Assumption 2 was satisfied. The experiment did not need area stratification. Two Kolmogorov-Smirnov (KS) statistical tests were used to determine if capture probability differed by size of fish. The first KS test compared the length frequency distribution of recaptured Arctic grayling with those released with marks during the marking event. The second KS test compared the length frequency distribution of Arctic grayling captured during the marking event with those captured in the recapture event. The first KS test was used to determine if there was size selectivity during the second event. If there was not, then stratification by length was not necessary. If there was, the second KS test was used to determine if size selectivity was the same for both events if it is unknown. If it is the same, then stratification is necessary. If is unknown, then the estimate is biased with or without stratification. The experiment needed to be stratified by size of fish because significant size-selective sampling was detected in the second event.

Assumptions 4 and 5 were assumed to be valid because of double marking of tagged Arctic grayling and rigorous examination of all captured Arctic grayling.

Calculation of Abundance

After mark-recapture data were stratified into size strata with equal capture probabilities, estimated abundance was calculated from number of Arctic grayling marked, examined for marks, and recaptured (Bailey 1951; Seber 1982):

$$\hat{N}_i = \frac{n_{1i}(n_{2i} + 1)}{m_{2i} + 1} \quad (1)$$

where:

n_{1i} = the number of Arctic grayling marked and released alive during the first sample in stratum i ;

n_{2i} = the number of Arctic grayling examined for marks during the second sample in

stratum i ; and,

m_{2i} = the number of Arctic grayling recaptured during the second sample in stratum i .

Variance was estimated by (Seber 1982):

$$\hat{V}[\hat{N}_i] = \frac{n_{1i}^2 (n_{2i} + 1)(n_{2i} - m_{2i})}{(m_{2i} + 1)^2 (m_{2i} + 2)}. \quad (2)$$

Bailey's (1951, 1952) modification was used instead of the modification by Chapman (1951) because of the systematic sampling design used for the experiment. Seber (1982) found that if the assumption of a random sample for the second sample was false but a systematic sample was taken (for example, a systematic sample of both banks of the Chena River), then the binomial model of Bailey (1951, 1952) is more appropriate.

Ninety-five percent confidence intervals for abundance were approximated as

$$\pm (t_{0.05\infty}) SE[N]. \quad (3)$$

ESTIMATION OF AGE AND LENGTH COMPOSITION

Collections of wild Arctic grayling for age-length samples were conducted in conjunction with abundance estimation experiments. Age composition was described with proportions of the stock contained in each age class. Size composition of Arctic grayling in each of the river sections was described with the incremental Relative Stock Density (RSD) indices of Gabelhouse (1984). The RSD categories are: "stock" (150 to 269 mm FL); "quality" (270 to 339 mm FL); "preferred" (340 to 449 mm FL); "memorable" (450 to 559 mm FL); and, "trophy" (greater than 559 mm FL). Incremental size composition was also estimated for each 10 mm increment of fork length from 150 mm to 450 mm.

From tests of assumptions 2 and 3 for estimation of abundance, significant differences in capture probability by size of fish were found. Age and size data were adjusted (p') for these differences so that the age and size composition of Arctic grayling in the lower 144 km of the Chena River could be estimated. First, the proportions of fish by age class or size category were estimated for each stratum used in estimation of abundance:

$$\hat{p}_{ik} = \frac{n_{ik}}{n_i} \quad (4)$$

where:

\hat{p}_{ik} = the estimated proportion in age or size category k fish sampled in stratum i ;

n_{ik} = the number of age or size category k fish sampled in stratum i ; and,

n_i = the number of fish sampled in stratum i .

Variance of this proportion was estimated using the variance of a binomial.

$$\hat{V}(\hat{p}_{ik}) = \frac{\hat{p}_{ik}(1 - \hat{p}_{ik})}{n_i - 1} \quad (5)$$

Next the abundance of each age class or size category was estimated from the proportions and abundance in each stratum:

$$\hat{N}_{ik} = \hat{p}_{ik} \hat{N}_i \quad (6)$$

where:

\hat{N}_{ik} = the estimated abundance of age or size category k fish sampled in stratum i.

Variance of each abundance at age or size was estimated with the formula for the variance of the product of two independent variables. After calculating abundances at age or size in each stratum, the overall proportions were estimated by:

$$\hat{p}_k = \sum_{i=1}^s \frac{\hat{N}_i}{\hat{N}_{ALL}} \hat{p}_{ik} \quad (7)$$

where:

\hat{p}_k = the estimated weighted proportion of Arctic grayling in the lower 144 km of the Chena River that were age or size k.

Variance of the proportions were approximated with the delta method (see Seber 1982):

$$\hat{V}[\hat{p}_k] \approx \sum_{i=1}^s \frac{(\hat{p}_{ik} - \hat{p}_k)^2 \hat{V}[\hat{N}_i]}{\hat{N}_{ALL}^2} + \sum_{i=1}^s \left(\frac{\hat{N}_i}{\hat{N}_{ALL}} \right)^2 \hat{V}[\hat{p}_{ik}]. \quad (8)$$

These estimated weighted proportions and variances by age and size were used as estimates of age and size compositions in the lower 144 km of the Chena River.

ESTIMATION OF SURVIVAL AND RECRUITMENT

Annual recruitment was defined as the number of age-5 Arctic grayling added to the population between year t and year t+1, and alive in year t+1. Estimates of recruitment were simply the estimates of abundance of age-5 Arctic grayling in 1996 and 1997. Variance of the recruitment estimates were the variance of abundance at age-5 for these same years. Prior to 1997, age at recruitment was age-3. In 1997, the lack of an abundance estimate of age-3 fish forced raising the age of recruitment to age-5 fish.

With recruitment and abundance at age estimates in years t and t+1, the estimate of survival rate between year t and year t+1 was:

$$\hat{S}_{t,t+1} = \frac{\hat{N}'_{t+1}}{\hat{N}_t} \quad (9)$$

where:

$\hat{N}'_{t+1} = \hat{p}'_{t+1} N_{t+1}$ is the abundance of age 6 and older Arctic grayling in year t+1 and \hat{p}'_{t+1} is the proportion of fish age 4 and older in year t + 1 with variance estimated by form (5); and,

$\hat{N}'_t = \hat{p}_t N_t$ is the abundance of age 5 and older Arctic grayling in year t and \hat{p} is the proportion of fish age 3 and older in year t with variance estimated by form (5).

The variance of \hat{N}'_{t+1} and \hat{N}_t is estimated from

$$\hat{V}[\hat{N}\hat{p}] \approx \hat{V}[\hat{N}]\hat{p}^2 + \hat{V}[\hat{p}]\hat{N}^2 \quad (10)$$

using the Delta methods (Seber 1982) and appropriate substitutions for \hat{N} and \hat{p} .

The variance of annual survival was approximated as the variance of a quotient of two independent variables with the delta method (Seber 1982):

$$\hat{V}[\hat{S}] \approx \left[\frac{\hat{N}'_{t+1}}{\hat{N}_t} \right]^2 \left[\frac{\hat{V}[\hat{N}'_{t+1}]}{\hat{N}'_{t+1}^2} + \frac{\hat{V}[\hat{N}_t]}{\hat{N}_t^2} \right]. \quad (11)$$

May Stock Assessment

May sampling commenced immediately following ice-out and covered the river from its mouth to river km 138 using the same electrofishing gear as in July. (The upper 6-km of the study area was not sampled due to low water conditions and ice-blocked access at river km 144.) Ice-out was monitored with ground-based surveys and two aerial surveys (Ridder 1998). Since Arctic grayling spawning behavior depends upon temperature and occupation of spawning sites usually range from 4 to 18 days (Ridder 1985, Beauchamp 1990), sampling began in the lower river and proceeded upstream to take advantage of the water temperature differences within the river. One boat was used to actively search for fish. Searching was not limited to one bank or the other but included other areas of the river. During spawning, adult fish use different portions of the river than at other times. Males spread out over riffle areas and females at heads of pools (Tack 1980, Van Wyhe 1964).

Sampling usually proceeded downstream in 20 - 25 min increments or runs, of approximately 1 to 2 km. However, due to small catches and time constraints in study section 6, two runs of 40 min were taken. After each run, all captured Arctic grayling ≥ 150 mm FL were sampled for length and age, marked with individually numbered tags and the right pectoral fin clipped. Each fish was sexed and the degree of maturity in females was noted. Either sexual dimorphism or the presence of milt or eggs was used to determine sex and maturity. Dimorphism is evident in differences in height and length of the dorsal fin and length of the pelvic fin (Bishop 1967); males have remarkably larger and longer dorsal fins and pelvic fins than females. In females, swollen anal vents and abdominal fullness (gravid) or flaccidity (spawned out) denoted states of maturity (Ridder 1989). When eggs were easily extruded, females were noted as being ripe. Clark (1992a) assessed the error associated with using these characteristics as sex and maturity indicators and found it negligible. Estimates of female maturity were presented in Ridder (1998). Adult males were used to describe the distribution of spawners since males are the first and last to occupy spawning sites (Beauchamp 1990).

May and July length distributions were compared with KS tests.

HISTORICAL DATA

Historical data referenced in this report can be found in Ridder (1998). Creel survey estimates, population abundance estimates, length at age estimates, age composition estimates, size composition estimates, and a model of Arctic grayling growth were summarized from reports written from 1959 to 1997. Other reports on the Arctic grayling of the Chena River include age and size at maturity estimates in 1991 and 1992 (Clark 1992a), influence of stream flows and stock size on recruitment (Clark 1992b), interannual intrastream movements for 1987 through 1992 (Clark 1993) and, seasonal movement patterns of adult Arctic grayling from radio telemetry (Ridder 1998). A list of electronic data files used in analyses for 1998 are found in Appendix A1.

RESULTS

The stock assessment of the Chena River in 1998 was conducted concurrently in both the lower and upper study sections with the first (marking) event occurring from 6 through 9 July and the second sampling (recapture) event from 13 through 16 July. A total of 3,355 Arctic grayling were captured of which 3,216 fish were unique. Of the unique fish, 188 fish were recaptured that were originally tagged during other studies. Of these, 94 fish were recaptured from 2,618 fish tagged and released in May 1998 (Ridder 1998; *Unpublished*). Water discharge from 6 through 16 July 1998 at the United States Geological Survey (USGS) gauging station at river kilometer 144 ranged from 12.5 m³s to 45.8 m³s (Figure 4) and averaged 24.7 m³s which was near the 31 year average (Figure 5).

Average water temperatures (°C) during stock assessment were similar to other years with the exception of 1997 (see Ridder 1998):

Year	Lower Chena Section				Upper Chena Section			
	n ^a	Low	High	Average	N	Low	High	Average
1991 ^b	3	12.5	14.5	13.2	Na	---	---	---
1992 ^b	8	12.1	14.0	13.2	9	9.0	12.5	10.8
1993 ^b	11	12.2	16.0	13.7	8	9.2	13.0	11.8
1994 ^b	10	9.2	14.1	11.3	8	8.5	11.2	10.2
1995 ^b	na	---	---	---	5	8.0	10.0	9.6
1996 ^b	5	11.8	13.5	12.9	Na	---	---	---
1997 ^b	9	14.5	18.7	16.1	14	10.9	16.2	13.2
1998 ^c	264	10.8	15.0	12.5	264	8.1	10.6	9.3

^a n= number of observations.

^b Temperatures taken with a mercury thermometer at various locations at start and end of various sample days.

^c Temperatures taken hourly with temperature loggers located at river km 72 (Chena Dam) for the lower section and at river km 150 for the upper section.

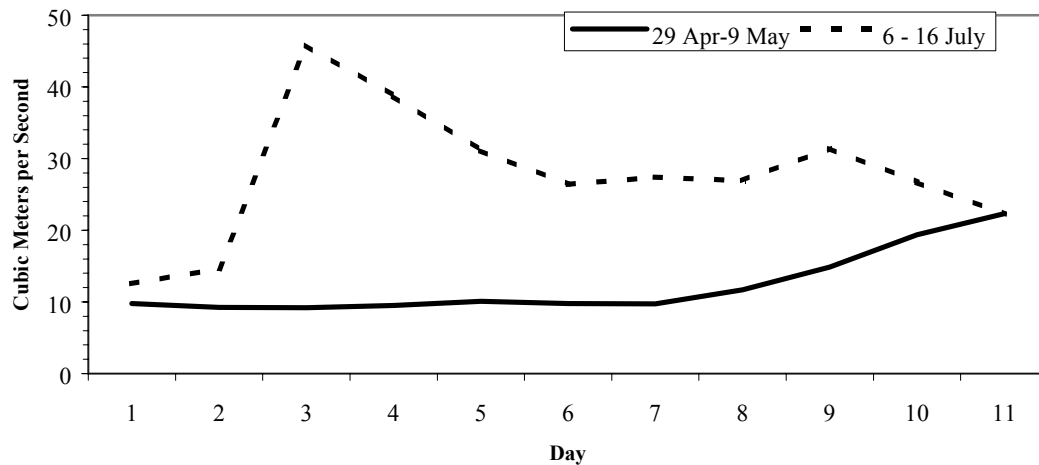


Figure 4.-Daily discharge (m^3/s) for the Chena River at river km 152 for 29 April - 9 May and 6 - 16 July 1998. (USGS *Unpublished*)

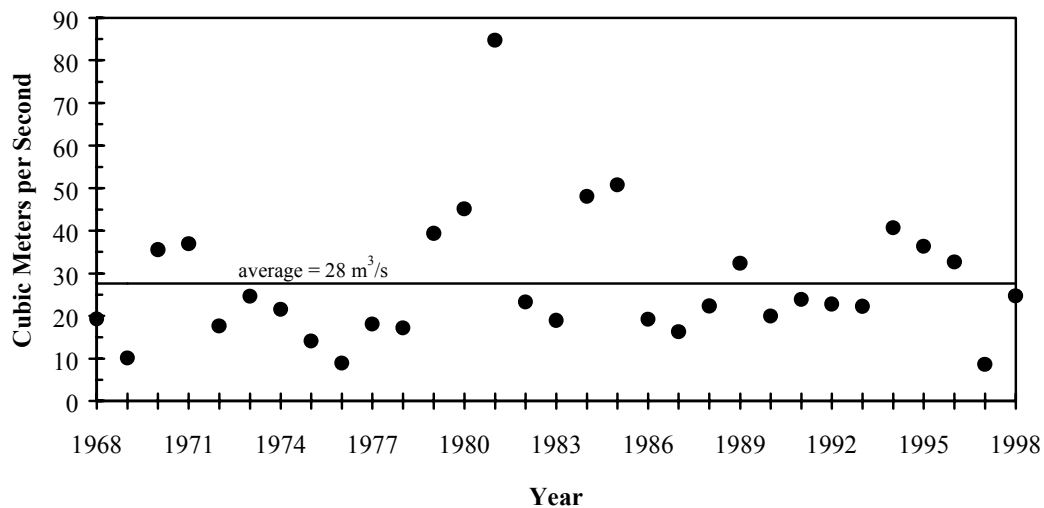


Figure 5.-Average discharge (m^3/s) for the Chena River at river km 152 for 1 - 15 July 1968 - 1998. (1968-1996 data from USGS: <http://www.water.usgs.gov/swr/ak/?statnum=15493000>; 1997 - 1998 data from USGS *Unpublished*).

LOWER CHENA SECTION

Within the lower section, 1,650 Arctic grayling were captured over the eight days of sampling. Twenty-seven (1.6%) immediate mortalities or serious injuries were recorded. Of the total, 819 fish were marked and released alive, 812 fish were examined for marks, and 97 fish were recaptured. Recapture-to-catch ratios did not vary significantly among four areas ($\chi^2 = 5.26$, $df = 3$, $P = 0.15$; Figure 6) indicating capture probability in the first event was similar among areas. Comparisons of length frequencies of marked fish with that of recaptured fish indicated that there was significant size-selective sampling in the second event ($D = 0.19$; $P < 0.01$; Figure 7), which necessitated stratification by length. The maximal chi-squared statistic occurred at a stratification of 150 to 221 mm FL for small fish and > 221 mm FL for large fish. Summing estimates of abundance from the two strata (Table 2), abundance of all Arctic grayling ≥ 150 mm FL in the lower section was 9,020 (SE = 1,550).

There was no significant difference in the length frequencies of fish marked versus those examined for marks in the lower section ($D = 0.06$; $P = 0.08$; Figure 7), which indicated that size selectivity was similar during both events. Therefore, samples from both events could be pooled to estimate composition of wild and hatchery-reared fish. However, ages were determined only from samples taken during the second event. Size and age composition was adjusted for unequal probabilities of capture by size.

Age-1 through age-12 were represented in the sample. Age-2 fish were the most abundant comprising 41% of the assessed population (Table 3). Stock-sized fish (150 – 269 mm) contributed 80% and preferred-sized fish (340 – 449 mm FL) 1% of the assessed population in the lower section of the Chena River (Table 4).

Four age-5 hatchery fish (1993 brood) were captured during the experiment. These fish composed $< 1\%$ of the catch. They ranged in size from 265 mm to 323 mm FL with a mean length of 289 mm FL (SD = 27). All were captured during the second event and comprised 3% of the age-5 fish sampled in the event. Age 6 hatchery fish (1992 brood) totaled 22 fish or 1% of the total catch. They ranged from 266 mm to 333 mm FL with a mean length of 291 mm (SD = 21). Twelve of these were captured in the second event and comprised 10% of all age-6 fish.

UPPER CHENA SECTION

Within the upper section, 1,698 Arctic grayling were captured out of which 29 (1.7%) immediate mortalities or serious injuries were recorded. Of the total, 728 fish were marked and released alive, 940 fish were examined for marks, and 42 fish were recaptures. The experiment did not need area stratification since recapture-to-catch ratios did not differ significantly among four areas of the upper section ($\chi^2 = 4.80$; $df = 3$; $P = 0.19$; Figure 6). Comparisons of length frequencies of marked fish with that of recaptured fish indicated that there was significant size-selective sampling in the second event ($D = 0.25$; $P = 0.02$; Figure 8) which necessitated stratification by length. The maximal chi-squared statistic occurred at a stratification of 150 to 331 mm FL for small fish and > 331 mm FL for large fish. Summing estimates of abundance from the two strata (Table 2), abundance of all Arctic grayling ≥ 150 mm FL in the upper section was 18,540 (SE = 3,250).

There was no significant difference in the length frequencies of fish marked versus those examined for marks in the upper section ($D = 0.06$; $P = 0.08$; Figure 8) which indicated that size

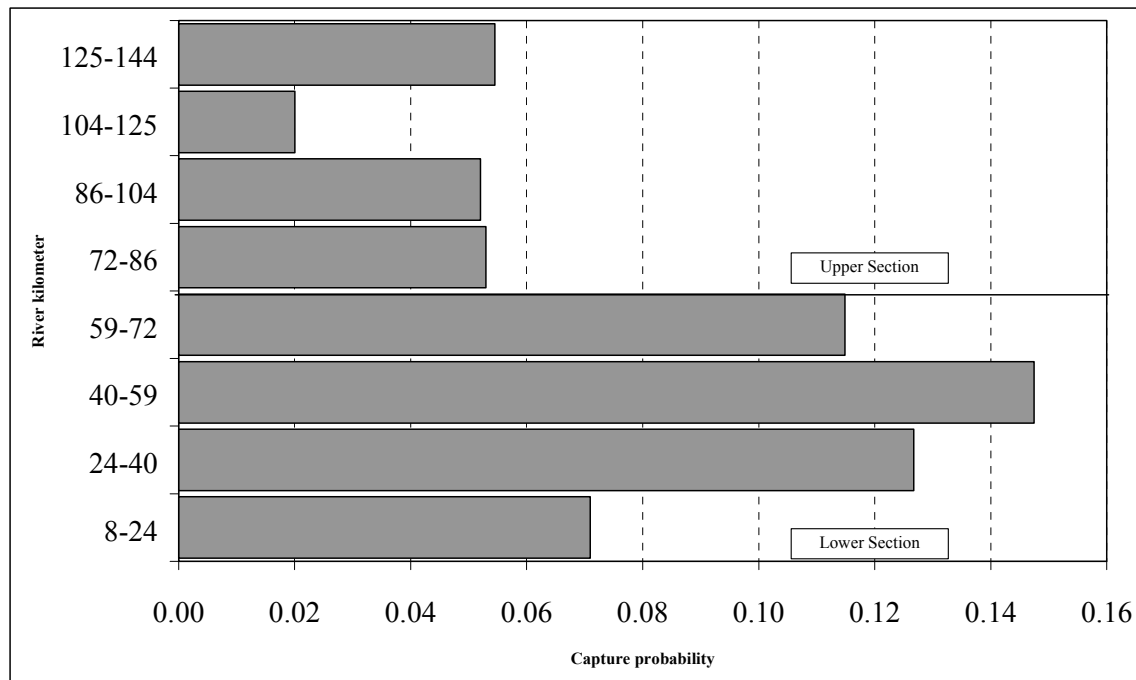


Figure 6.-Recapture-to-catch ratios of Arctic grayling (≥150 mm FL) in eight reaches of the Chena River in 1998.

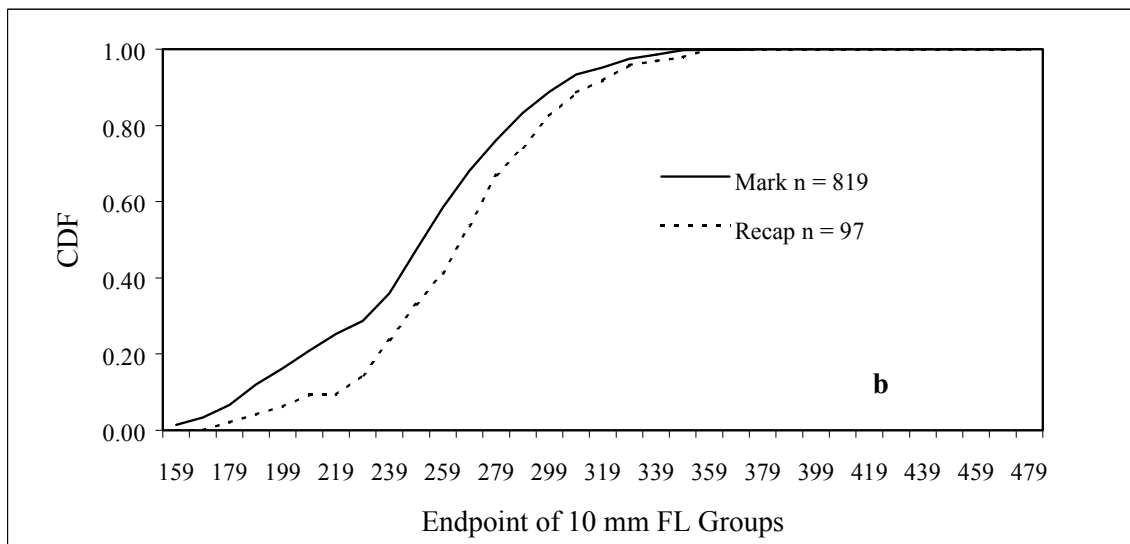
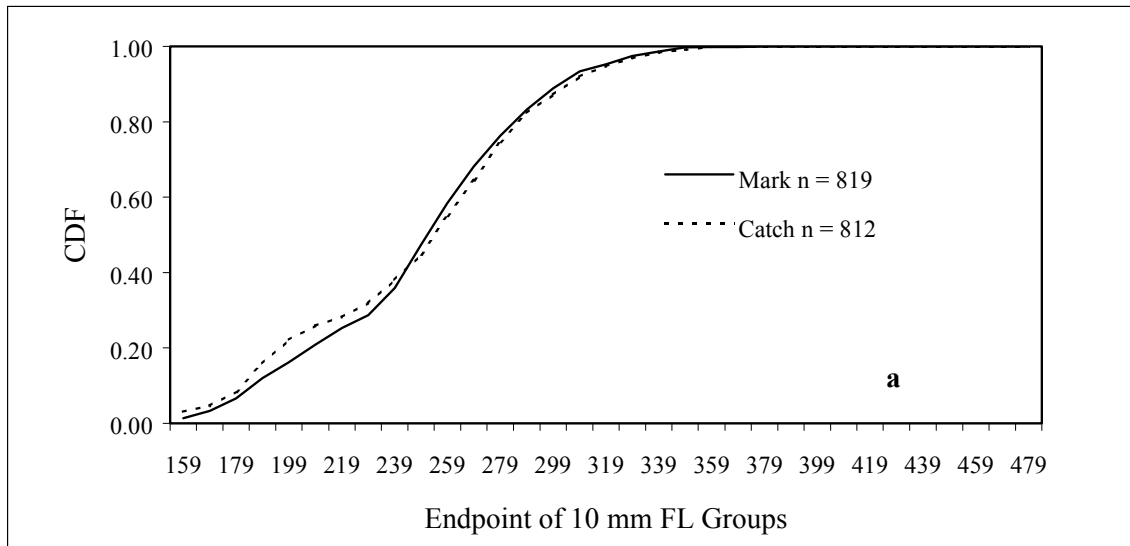


Figure 7.-Cumulative distribution functions (CDF) of fork length of Arctic grayling marked versus captured (a) and marked versus recaptured (b) in the lower section of the Chena River, 6 through 16 July 1998.

Table 2.-Capture probabilities and estimated abundance used for population estimation of Arctic grayling (≥ 150 mm FL) in the lower and upper sections of the Chena River study area, 6 through 16 July 1998.

Section	Stratum	Mark (n_1)	Catch (n_2)	Recap (m_2)	m_2/n_2^a	N^b	$SE[N]^c$
Lower	Small ^d	217	234	9	0.04	5,100	1,500
	Large ^e	602	578	88	0.15	3,920	380
	Total	819	812	97	0.12	9,020	1,550
Upper	Small ^f	596	747	25	0.03	17,120	3,240
	Large ^g	132	193	17	0.09	1,420	310
	Total	728	940	42	0.04	18,540	3,250

^a m_2/n_2 is the probability of capture.

^b N is the estimated abundance in a stratum.

^c $SE [N]$ is the standard error of N .

^d Small is fish 150 - 221 mm FL.

^e Large is fish > 221 mm FL.

^f Small is fish 150 - 321 mm FL.

^g Large is fish > 321 mm FL.

Table 3.-Estimates of age composition, length at age, and abundance by age class with standard errors for Arctic grayling (≥ 150 mm FL) captured by pulsed-DC electrofishing from the lower section of the Chena River, 6 through 16 July 1998.

Age	Age Composition			Length at Age (mm FL)				Abundance		
	n ^a	p' ^b	SE[p']	Mean	SD	Min	Max	N ^c	SE[N]	CV ^d
1	22	0.06	0.01	154	4	150	161	542	191	35%
2	152	0.41	0.06	187	18	150	280	3,695	1,094	30%
3	43	0.08	0.01	223	25	176	296	694	188	27%
4	69	0.08	0.01	241	23	205	327	719	126	18%
5	156	0.14	0.03	257	18	171	317	1,283	149	12%
6	119	0.11	0.02	275	25	156	333	986	123	13%
7	71	0.06	0.01	288	26	216	350	585	86	15%
8	29	0.03	0.01	300	20	254	337	232	47	20%
9	14	0.01	0.00	310	28	259	356	112	31	28%
10	12	0.01	0.00	311	35	248	365	96	29	30%
11	7	0.01	0.00	329	11	314	344	56	22	39%
12	2	0.00	0.00	323	32	300	345	16	11	71%
Total	696	1.00	---	247	47	150	365	9,016	1,550	---

^a n= number of Arctic grayling sampled at age.

^b p'= estimated adjusted proportion of Arctic grayling at age in the population.

^c N= estimated population abundance of Arctic grayling at age.

^d CV = coefficient of variation.

Table 4.-Summary of Relative Stock Density (RSD) indices of Arctic grayling (≥ 150 mm FL) captured in A: the lower section, B: the upper section, and C: combined, Chena River 1998.

		RSD Category ^a				
		Stock	Quality	Preferred	Memorable	Trophy
A:	Number Sampled	1,031	482	21	0	0
	Adjusted RSD ^b	0.80	0.19	0.01	---	---
	SE (RSD)	0.14	0.03	<0.01	---	---
	N	7,212	1,728	75	0	0
	SE (N)	1,520	178	18	---	---
B:	Number Sampled	464	925	237	0	0
	Adjusted RSD ^b	0.33	0.62	0.06	---	---
	SE (RSD)	0.01	0.02	0.02	---	---
	N	6,028	4,424	1,095	0	0
	SE (N)	1,161	2,111	242	---	---
C:	Number Sampled	1,495	1,407	258	0	0
	Adjusted RSD ^b	0.48	0.48	0.04	---	---
	SE (RSD)	0.03	0.03	0.04	---	---
	N	13,241	13,152	1,170	0	0
	SE (N)	1,632	2027	195	---	---

^a Minimum lengths for RSD categories are (Gabelhouse 1984): Stock – 150 mm FL; Quality – 270 mm FL; Preferred – 340 mm FL; Memorable – 450 mm FL; and, Trophy – 560 mm FL.

^b Adjusted RSD is the RSD corrected for differential vulnerability by length to the capture method. Standard error of RSD is for the adjusted estimate.

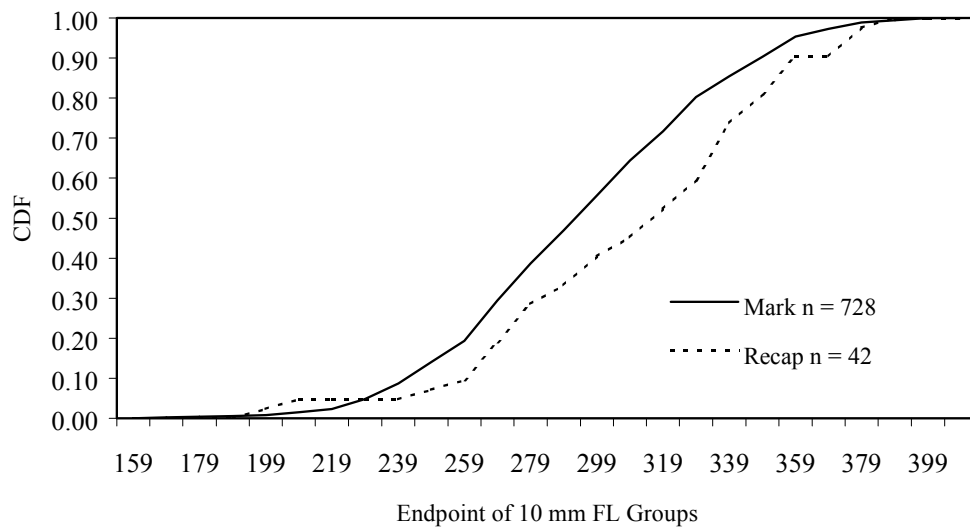
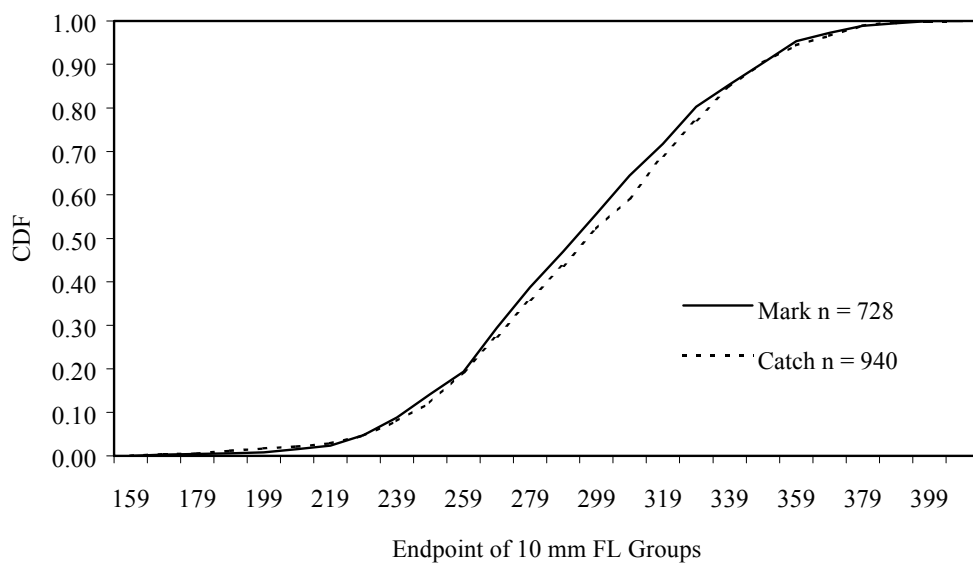


Figure 8.-Cumulative distribution functions (CDF) of fork length of Arctic grayling marked versus captured (a) and marked versus recaptured (b) in the upper section of the Chena River, 6 through 16 July 1998.

selectivity was similar during both events. Therefore samples from both events were pooled to estimate composition. However, ages were determined only from the second event. Size and age composition was adjusted for unequal probabilities of capture by size.

Age classes 2 through 13 were represented in the sample (Table 5). Age 5 fish were most abundant, contributing 30% of the estimated abundance (Table 5). Unlike the lower section, stock-size fish (150 – 269 mm FL) contributed only 33% of the assessed abundance in the upper section while 62% of fish were of quality-size (270 – 339 mm FL; Table 4).

Three age 5 hatchery fish (1993 brood) were captured in both events which was <1% of the catch. They ranged in size from 277 mm to 308 mm FL with a mean length of 289 mm FL (SD = 17). One fish was caught in the second event and comprised <1% of all age-5 fish. Age 6 hatchery fish (1992 brood) totaled 11 fish and comprised <1% of the catch. They ranged from 241 mm to 352 mm FL with a mean length of 298 mm (SD = 31). Six of these were caught in the second event and represented 4% of all age-6 fish.

CHENA RIVER TOTAL

Summing estimated abundance from the lower and upper sections resulted in an estimate of 27,563 Arctic grayling (≥ 150 mm FL; SE = 3,604; Table 6) in the lower 144 km of the Chena River in July 1998. Age-5 fish were most abundant composing 25% of the estimated abundance. Stock and quality-size fish each composed 48% of estimated abundance and preferred-size only 4% of (Table 4). Survival rate of age-5 and older fish in 1997 to age-6 and older fish in 1998 was 90.5% (SE = 11.0, Table 7). Recruitment from 1997 to 1998 (age-5 fish) was 6,834 fish (SE = 1,047, Table 7).

Hatchery-reared fish contributed 1.3% ($n = 40$) to the 3,160 Arctic grayling captured in the experiment. The 23 hatchery fish caught in the second event represented 4% of the age-5 and age-6 fish sampled. Abundance was not estimated because of the small sample size.

MAY SAMPLING

Between 29 April and 9 May, 2,632 Arctic grayling (≥ 150 mm FL) were captured from the mouth to river kilometer 138. One fish, an adult male, was caught twice after moving upstream 6 km in 48 h. Of the 2,631 fish unique to the sample, 14 fish were immediate mortalities, 70 fish were recaptured from other studies, and 2,617 fish were released alive with tags. Adult males accounted for 49% of the catch ($n = 1,282$), and adult females and fish of unknown sex were near equally represented (Table 8). All males were ripe, 76% (SE = 2%, $n = 476$) of females were green, 17% (SE = 4%, $n = 109$) were ripe, and 6% (SE = 2%, $n = 36$) were spent. Adult males were distributed throughout the sampling area but were most numerous in study reaches 2, 3, and 8 (Table 8). The greatest concentration of males was found within 6 km above the mouth of the Little Chena River (Figure 9).

A greater proportion of large fish were in the May sample compared to the July sample, especially in the lower section (Figure 10; Tables 4 and 9). The length composition of the May sample was significantly different than that of the July sample in the lower section ($D = 0.47$; $P \leq 0.01$), in the upper section ($D = 0.18$; $P \leq 0.01$), and combined sections ($D = 0.31$; $P \leq 0.01$; Figure 11). Quality and larger sized fish comprised over 70% of the May sample in the lower, upper, and combined sections (Table 9). Memorable sized fish comprised over 20% of the catch in each section during May but only 1% to 4% in July (Table 4).

Table 5.-Estimates of age composition, length at age and abundance by age class with standard errors for Arctic grayling captured by pulsed-DC electrofishing from the upper section of the Chena River, 6 through 16 July 1998.

Age	Age Composition			Length at Age (mm FL)				Abundance		
	N ^a	p' ^b	SE[p']	Mean	SD	Min	Max	N ^c	SE[N]	CV ^d
2	8	0.01	0.00	191	25	164	230	209	82	39%
3	16	0.02	0.01	201	14	178	223	417	128	31%
4	74	0.10	0.01	247	22	196	333	1,912	415	22%
5	213	0.30	0.02	270	20	224	326	5,552	1,094	20%
6	157	0.21	0.02	297	23	240	348	3,839	751	20%
7	153	0.18	0.01	317	26	248	384	3,262	603	18%
8	92	0.10	0.01	322	28	232	378	1,858	360	19%
9	47	0.05	0.01	334	27	253	404	837	181	22%
10	25	0.02	0.00	345	24	280	382	348	91	26%
11	19	0.01	0.00	354	22	317	386	225	66	29%
12	7	0.00	0.00	360	20	320	377	81	36	44%
13	1	0.00	0.00	370		370	370	9	9	100%
Total	812	1.00	1.00	296	41	164	404	18,547	3,250	---

^a n = number of Arctic grayling.

^b p' = adjusted estimated proportion of Arctic grayling at age in the population.

^c N = estimated population abundance.

^d CV = coefficient of variation.

Table 6.-Age composition and estimates of abundance by age class for Arctic grayling ≥ 150 mm FL captured by pulsed-DC electrofishing from the Chena River, 6 through 16 July 1998.

Age Class	N ^a	SE [N]	p ^b	SE [p]
1	542	194	0.02	0.01
2	3,904	1,101	0.14	0.04
3	1,111	235	0.04	0.01
4	2,631	423	0.10	0.01
5	6,834	1,047	0.25	0.02
6	4,825	748	0.18	0.01
7	3,847	609	0.14	0.01
8	2,090	363	0.08	0.01
9	949	193	0.03	0.01
10	444	109	0.02	<0.01
11	281	80	0.01	<0.01
12	97	40	0.00	<0.01
13	9	9	0.00	<0.01
Total	27,563	3,604	1.00	---

^a N = estimated population abundance of Arctic grayling at age.

^b p = estimated adjusted proportion of Arctic grayling at age.

Table 7.-Summary of population abundance, annual survival (%), annual recruitment, and standard error estimates during 1987-1998 for Arctic grayling (\geq age-5) in the lower 144 km of the Chena River.

Year	N ^a	SE [N]	S ^b	SE [S]	B ^c	SE [B]
1987	8,292	720	59.1	4.4	2,370	511
1988	14,327	940	46.9	5.6	9,423	868
1989	9,279	862	71.2	9.2	2,563	500
1990	9,034	987	54.4	7.9	2,429	489
1991	7,883	621	54.0	5.8	2,966	404
1992	15,437	1,120	44.3	7.2	11,178	1,077
1993	10,357	1,184	77.1	10.6	3,520	632
1994	11,164	697	50.1	5.8	3,178	343
1995	14,063	1,168	91.3	9.5	8,471	1,033
1996	19,668	1,206	51.3	6.3	6,834	892
1997	13,857	1,205	90.5	11.0	3,774	560
1998	19,376	1,488	---	---	6,834	1,047
Averages^d						
1987-1998	12,728	1,089	60.8	7.5	5,295	761
1987-1990	10,233	963	57.2	6.8	4,196	623
1991-1998	13,976	1,119	62.9	7.7	5,844	799

^a N is the abundance of age-5 and older Arctic grayling. Excludes 1992 brood of stocked fish in 1997. Includes 1993 brood of stocked fish in 1998.

^b S is the survival from that year to the next year.

^c B is recruitment of age-5 Arctic grayling during that year.

^d Average of survival rate is the geometric mean.

Table 8.-Catch by sex of Arctic grayling and density of males per km in eight study reaches of the lower 138 km of the Chena River, 29 April through 9 May 1998.

Date	Reach	River km	Females	Males	Unknowns	Catch	#Males/km
5/1/1998	01	0-24	43	144	46	233	6
4/29/1998	02	24-40	64	207	85	356	13
5/5/1998	03	40-56	112	326	90	528	20
5/4/1998	04	56-72	56	132	68	256	8
5/7/1998	05	72-90	77	134	90	301	8
5/6/1998	06	90-107	19	67	44	130	4
5/8/1998	07	107-125	71	81	183	335	5
5/9/1998	08	125-138	184	191	117	492	15
Total		0-138	626	1,282	723	2,631	9

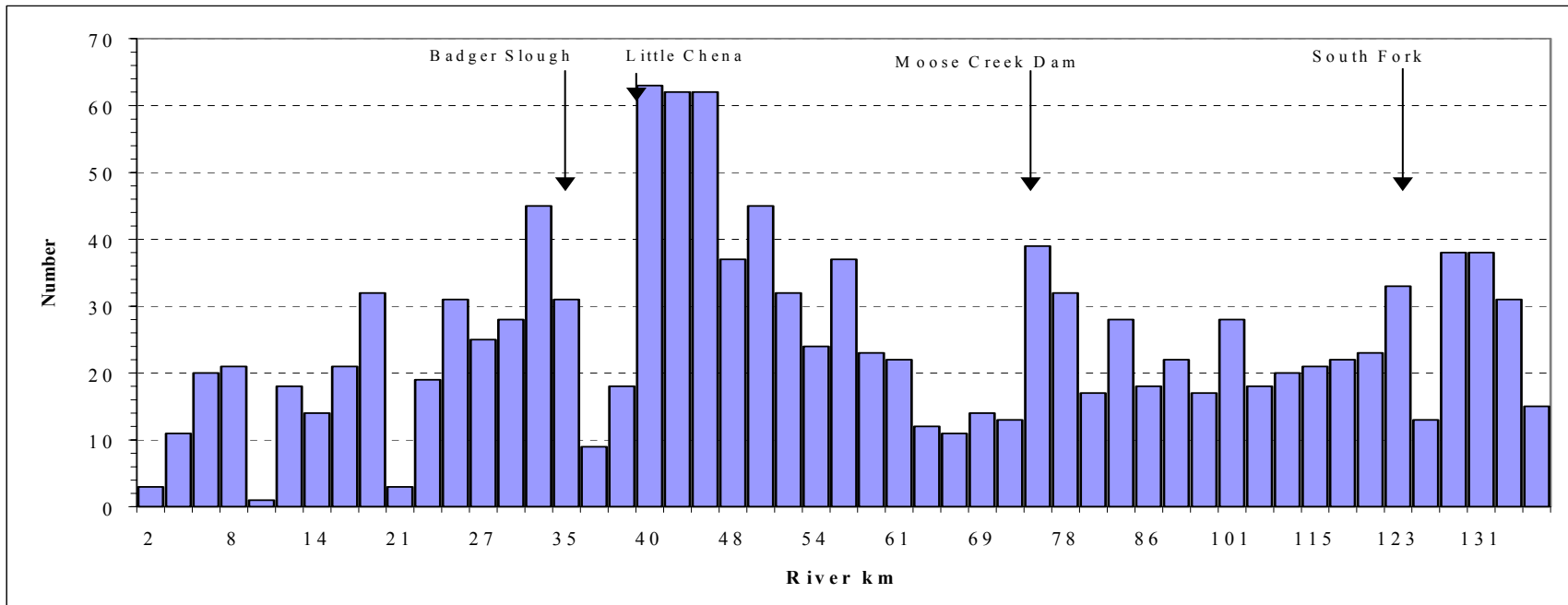


Figure 9.-Numbers of adult male Arctic grayling caught in 2 to 5 km sampling runs along the lower 138 km of the Chena River, 29 April through 9 May 1998.

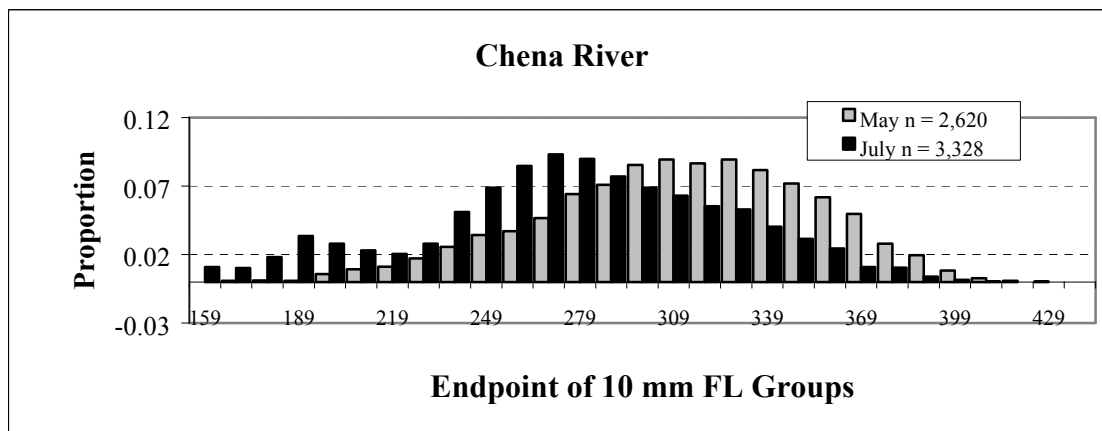
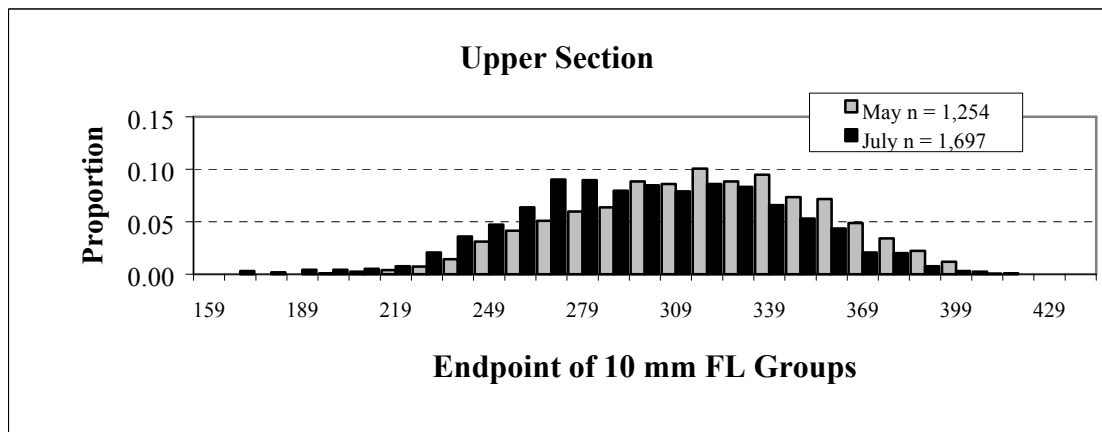
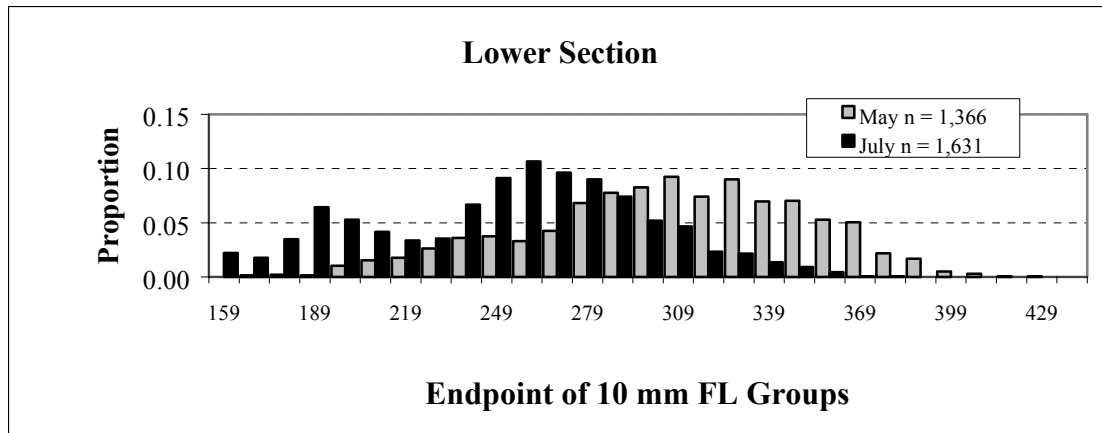


Figure 10.-Length frequencies of Arctic grayling captured in the lower, upper, and combined study sections of the Chena River in May and July 1998.

Table 9.-Summary of Relative Stock Density (RSD) indices of Arctic grayling (≥ 150 mm FL) captured in the lower section, the upper section, and combined, Chena River May 1998.

	RSD Category ^a				
	Stock	Quality	Preferred	Memorable	Trophy
Lower Section					
Number Sampled	303	753	303	0	0
RSD	0.22	0.55	0.22	---	---
SE (RSD)	0.01	0.01	0.01	---	---
Upper Section					
Number Sampled ≥ 150	189	728	333	0	0
RSD	0.15	0.58	0.27	---	---
SE (RSD)	0.01	0.01	0.01	---	---
Combined Sections					
Number Sampled	492	1,481	636	0	0
RSD	0.19	0.57	0.24	---	---
SE (RSD)	0.01	0.01	0.01	---	---

^a Minimum lengths for RSD categories are (Gabelhouse 1984): Stock – 150 mm FL; Quality – 270 mm FL; Preferred – 340 mm FL; Memorable – 450 mm FL; and, Trophy – 560 mm FL.

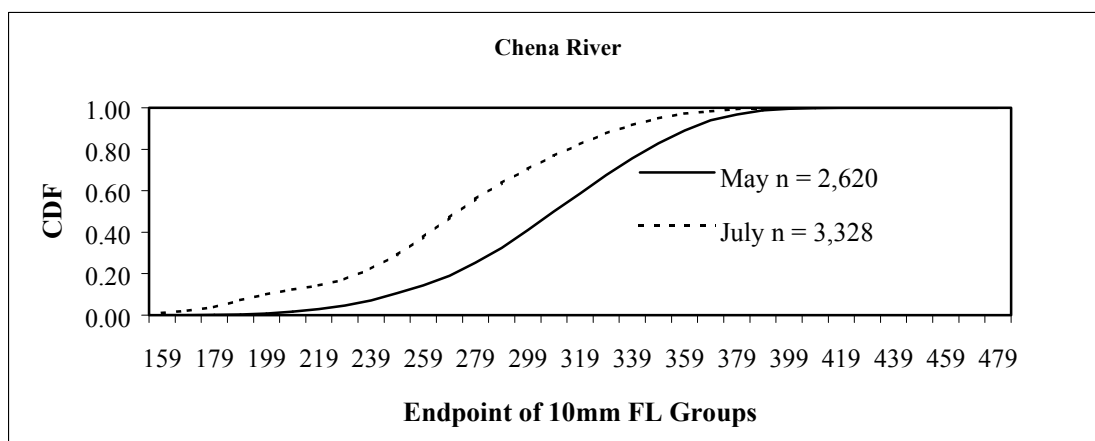
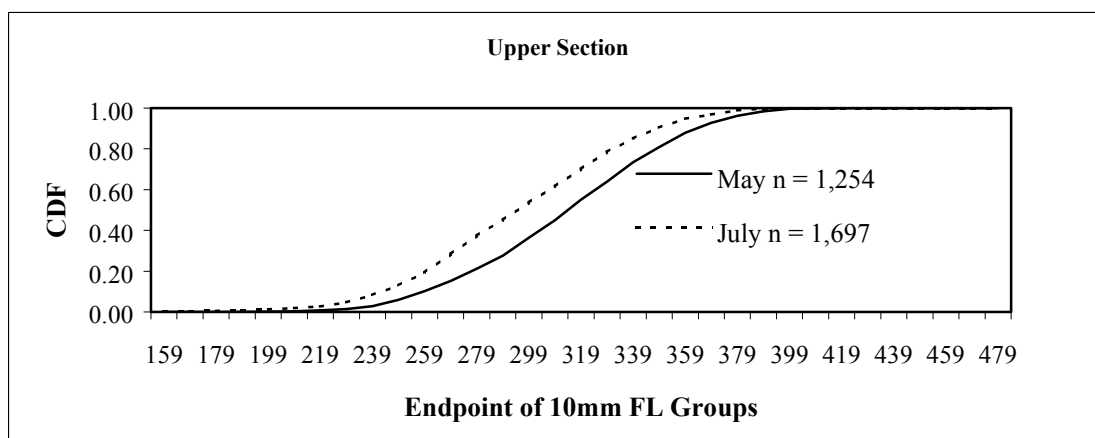
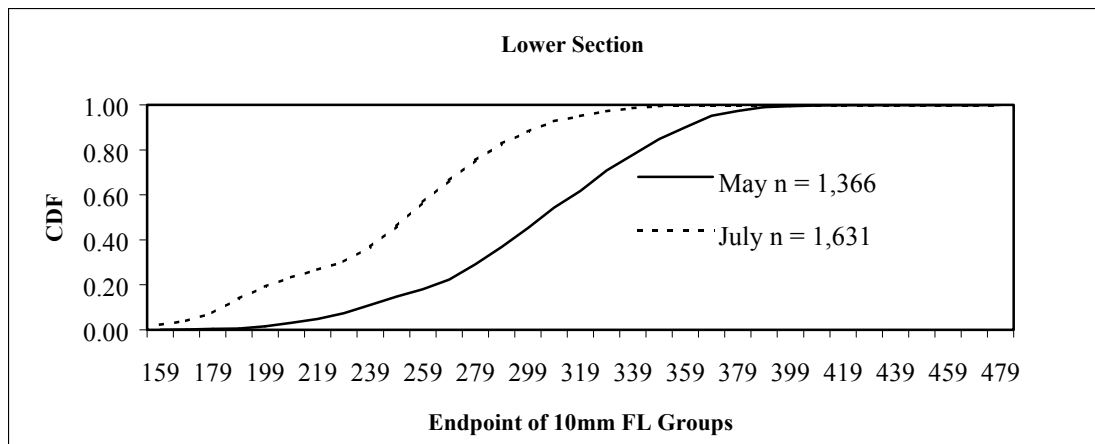


Figure 11.-Cumulative distribution functions (CDF) of fork length of Arctic grayling captured in May versus Arctic grayling captured in July in the lower, upper, and combined section of the Chena River, 1998.

During the July mark-recapture experiment, 94 tagged fish from the May sample were recaptured, or 2.9% (SE = 0.3%) of the catch of unique fish. Movement of the recaptures was predominantly upstream (Table 10). Ten fish moved downstream 1 to 8 km and 7 fish remained in the area of release (Table 11). Movements from release sites ranged from 8 km downstream to 83 km upstream, averaged 26 km upstream (SD = 17 km) and had a median of 16 km.

DISCUSSION

The present assessment program for the Chena River Arctic grayling population has been in place since 1987. It was undertaken to provide managers with accurate and precise estimates of abundance, recruitment, and survival with which to assess the regulatory changes in 1987 (spring closures and 305 mm TL limit) which were designed to rebuild the population. The response of the population to these regulations, which changed to catch and release in 1991, has been mixed depending upon the parameter being considered. For abundance, the population has shown variability from 1987 through 1998 (Figure 12). From a high of 45,100 fish in 1995, the July abundance of Arctic grayling ≥ 150 mm in the lower 144 km of the Chena River declined significantly to 27,500 fish in 1998. For recruitment, levels have been quite variable from 1987 through 1998 when defined as age-3 fish (the youngest age fully represented in samples of fish ≥ 150 mm) and less so when defined as age-5 fish (Figure 12; Table 7). However, it is recruitment of young fish, ages 2 – 4, that influences assessed abundance in the study area. Clark (1992b) found that 60% of the variability in age-3 recruitment from year a to year b was explained by river discharge around the time of hatching and that, based on limited data, parental stock size had no influence on the size of this recruitment. Thus, recruitment and eventually, abundance can be considered strongly dependent on an environmental variable. The two successive years of strong age-3 recruitment in 1993 and 1994 resulted in the relatively high abundance from 1993 through 1996. Alternatively, the two successive years of poor age-3 recruitment found in the lower study section in 1997 (recruitment estimate was not obtained in the upper section; Ridder 1998) and in both study sections in 1998 resulted in a 1998 abundance no different than when regulatory relief was implemented in 1987. For annual survival, average rates, for both age-3 fish and older (Ridder and Fleming 1997) and age-5 and older (Table 7), are not significantly different than those estimated before the regulation.

A consideration of compositional changes in the population gives a more positive picture of its response to regulatory changes. The trend in the abundance of stock-sized fish (150 - 269 mm FL), predominantly age-3 and age-4 fish but including some age-2 and age-5 fish, follows the cyclical trend of the population due, as stated above, to the influence of variable recruitment (Figure 13; Table 12). The decline in stock size fish was most notable in the upper section where the 1998 abundance was low and, for the first time, lower than stock-sized abundance in the lower section. In contrast, the trend in abundance of quality-size and larger fish (≥ 270 mm FL) has been steadily increasing under the no harvest regulation to an eight-year high of 14,322 fish in 1998 (Figure 14; Table 12). This increase has come largely in the upper section. In the lower section, abundance of quality size fish has always been less than in the upper section and, with the exception of 1996, has remained essentially unchanged from 1991 through 1998 (Figure 14; Table 12). This situation likely reflects Arctic grayling behavior where older and larger fish prefer upstream areas for summer feeding (Tack 1980; Ridder 1998). The future abundance of these fish in the population is not expected to decline significantly despite the recent poor recruitment of age-3 fish. Quality-sized and larger fish are somewhat buffered from year class

Table 10.-Number of Arctic grayling released in May and recaptured in July by study reach, Chena River 1998.

Reach of Release	Reach of Recapture								Total
	01	02	03	04	05	06	07	08	
01	1	1	1	1		3		1	8
02		4				2			6
03		1	8	4	3	2	1	2	21
04				4	4	2	1	5	16
05					4	8	1	3	16
06					1	2	1	3	7
07						2	8	5	15
08								5	5
Total	1	6	9	9	12	21	12	24	94

Table 11.-Direction moved, number of fish, estimated proportions, and standard error of proportions for Arctic grayling that were released in May and recaptured in July, Chena River 1998.

km Moved	n	p	SE[p]
-1 - -8	10	0.11	0.03
0	7	0.07	0.03
1 – 8	18	0.19	0.04
9 – 16	15	0.16	0.04
17 – 24	8	0.09	0.03
25 – 32	6	0.06	0.03
33 – 40	8	0.09	0.03
41 – 48	5	0.05	0.02
49 – 56	0	---	---
57 – 64	4	0.04	0.02
65+	13	0.14	0.04
Total	94	1.00	---

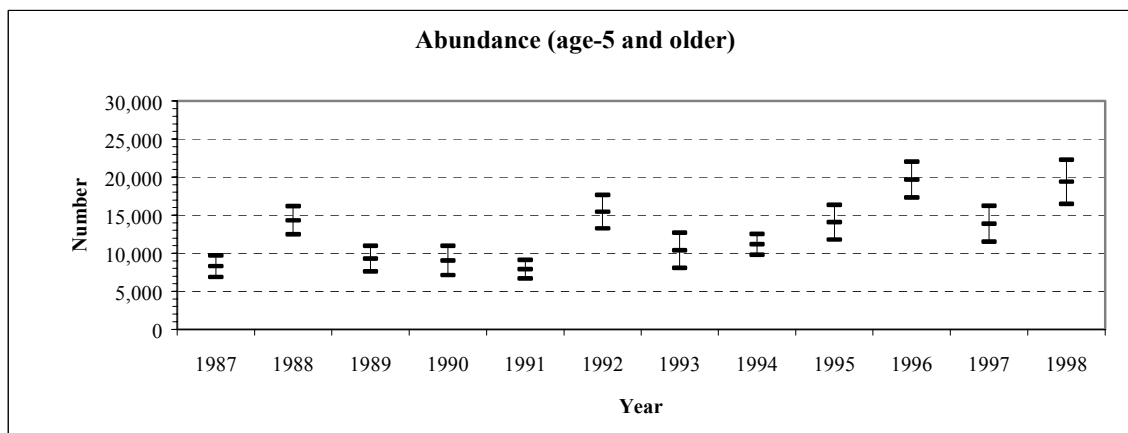
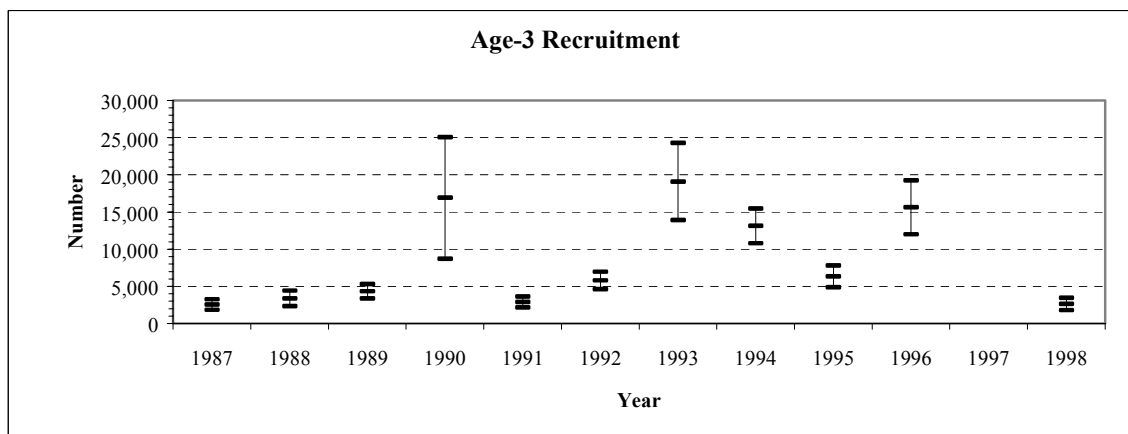
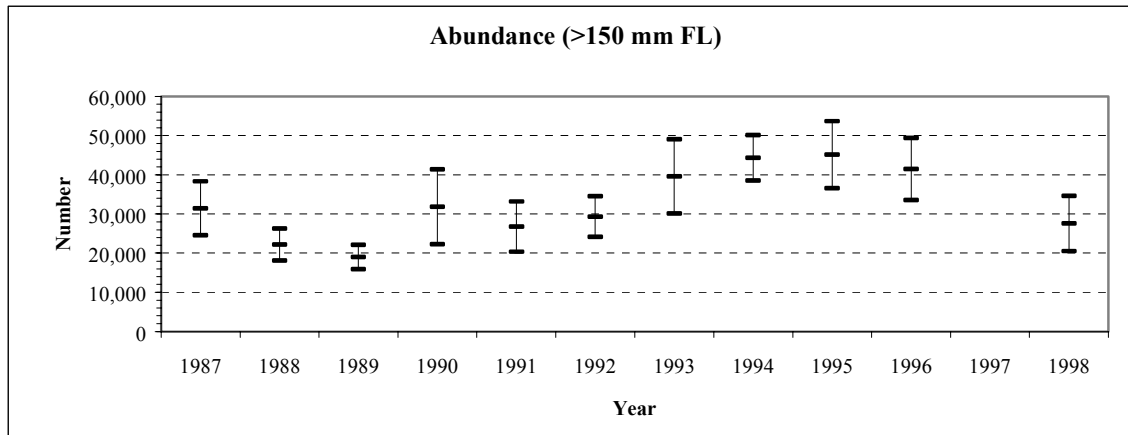


Figure 12.-Estimates of abundance and recruitment and 95% confidence intervals for wild Arctic grayling in the Chena River study area, 1987-1998.

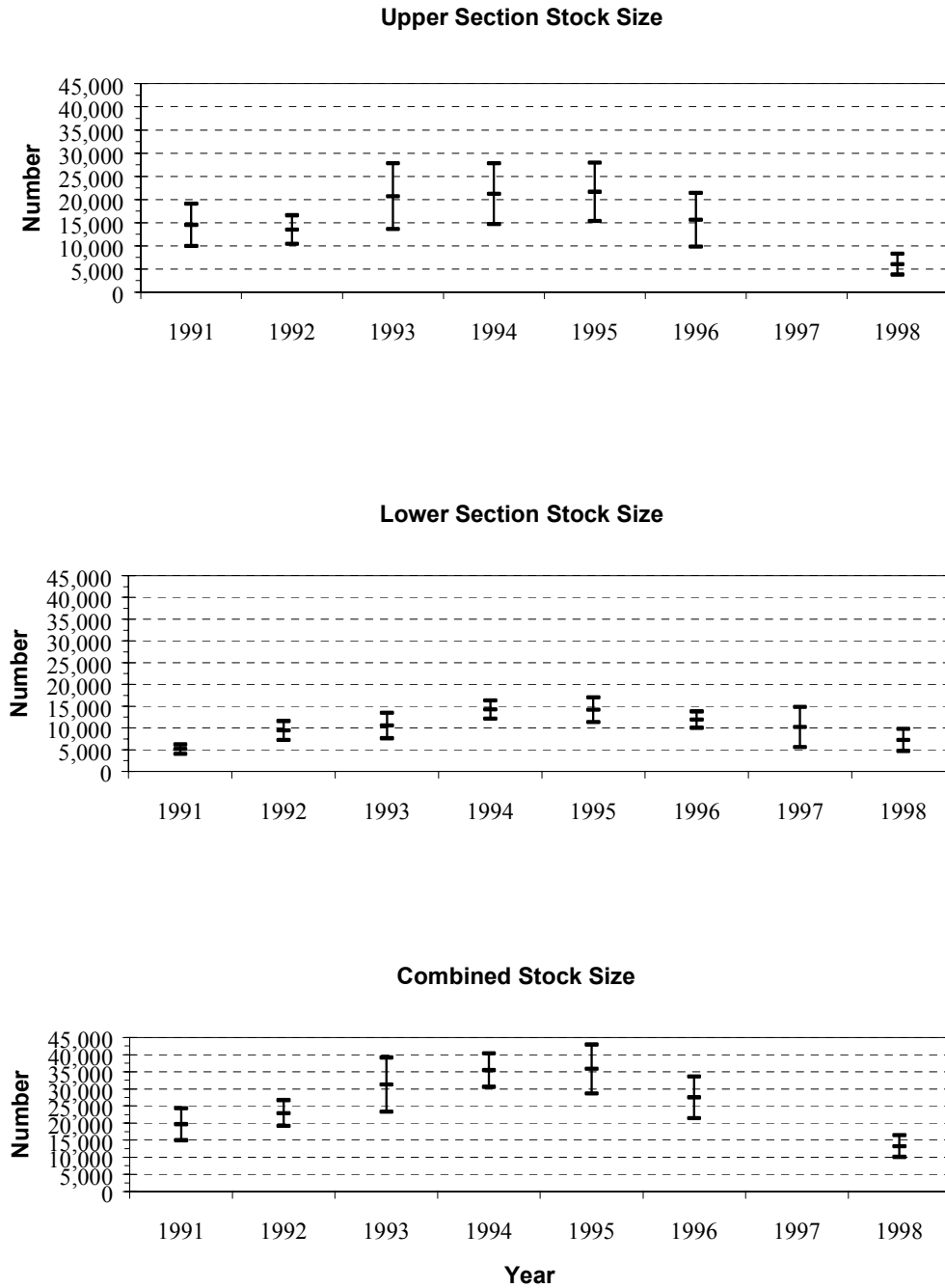


Figure 13.-Abundance and 95% confidence intervals of stock-sized Arctic grayling (150 – 269 mm FL) in the upper, lower, and combined study sections of the Chena River, 1991 – 1998.

Table 12.-Abundance, standard errors and 95% confidence intervals of stock and quality-sized and larger wild Arctic grayling (≥ 270 mm FL) in the upper, lower, and combined study sections of the Chena River, 1991-1998.

Year	Stock Size (150 – 269 mm)			Quality and Larger (≥ 270 mm)		
	N	SE [N]	95% CI	N	SE [N]	95% CI
Lower Section						
1991	5,100	561	4,000 - 6,200	1,426	188	1,058 - 1,794
1992	9,394	1,108	7,222 - 11,566	1,921	338	1,259 - 2,583
1993	10,514	1,492	7,590 - 13,438	1,533	311	923 - 2,143
1994	14,200	1,085	12,073 - 16,327	2,335	274	1,797 - 2,873
1995	14,150	1,450	11,308 - 16,992	2,059	294	1,482 - 2,636
1996	11,863	962	9,977 - 13,749	2,780	245	2,300 - 3,260
1997	10,205	2,348	5,603 - 14,807	2,044	374	1,310 - 2,778
1998	7,212	1,520	4,701 - 9,723	1,804	427	966 - 2,640
Upper Section						
1991	14,513	2,328	9,950 - 19,076	5,717	846	4,059 - 7,375
1992	13,495	1,570	10,418 - 16,572	4,538	647	3,270 - 5,806
1993	20,694	3,627	13,585 - 27,803	6,877	1,486	3,965 - 9,789
1994	21,239	3,350	14,673 - 27,805	6,601	1,228	4,194 - 9,008
1995	21,660	3,209	15,370 - 27,950	7,276	1,292	4,743 - 9,809
1996	15,611	2,970	9,790 - 21,432	11,209	1,229	8,801 - 13,617
1997	nd ^a	---	---	9,458	1,688	6,149 - 12,767
1998	6,028	1,161	3,753 - 8,304	12,519	2,051	8,499 - 16,539
Combined Sections						
1991	19,613	2,395	14,919 - 24,307	7,143	867	5,444 - 8,842
1992	22,889	1,921	19,124 - 26,654	6,459	730	5,029 - 7,889
1993	31,208	4,028	23,313 - 39,103	8,410	1,470	5,529 - 11,291
1994	35,439	2,498	30,543 - 40,335	8,936	876	7,220 - 10,652
1995	35,810	3,636	28,683 - 42,937	9,335	1,273	6,840 - 11,830
1996	27,474	3,121	21,357 - 33,591	13,989	1,252	11,536 - 16,442
1997	nd ^a	---	---	11,502	1,729	8,112 - 14,892
1998	13,241	1,632	10,042 - 16,436	14,322	1,840	10,716 - 17,928

^a nd = no data. Abundance of stock-sized fish could not be estimated in the upper section in 1997.

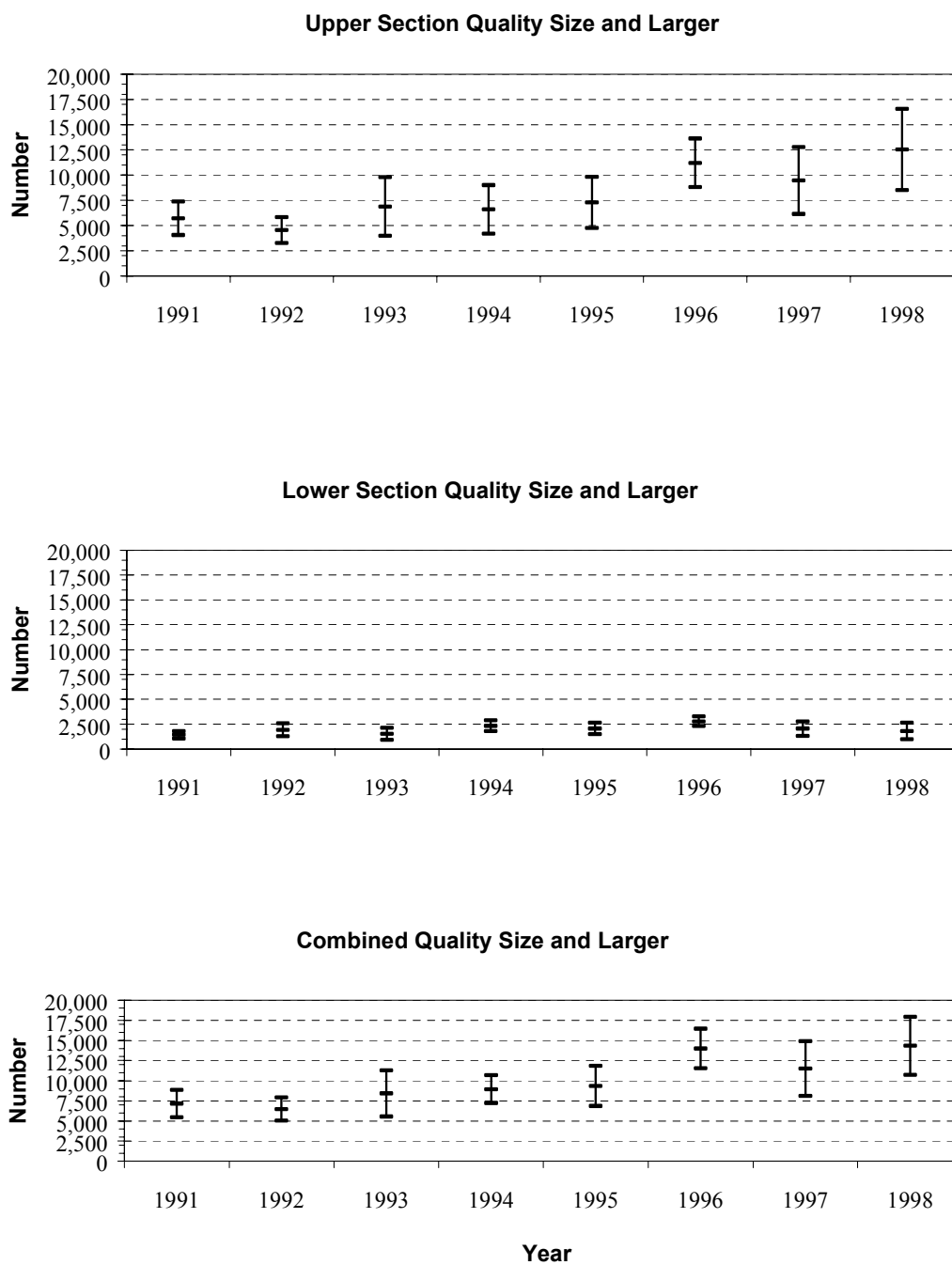


Figure 14.-Abundance and 95% confidence intervals of quality-sized and larger Arctic grayling (≥ 270 mm FL) in the upper, lower, and combined study sections of the Chena River, 1991 – 1998.

variability because they are composed of at least nine age classes whereas stock size fish largely include just four classes.

The compositional shift to larger fish indicates that the biomass of the population has increased and is greater than that in 1991. Recent effort and catch estimates in the fishery are near double those of 1991. Anecdotal reports from anglers describe excellent fishing over the last four years. The large composition of age-2 fish found in 1998 also suggests excellent recruitment of this year class in 1999 that will likely increase overall abundance. Considering all the above, the status of Chena River Arctic grayling is considered good.

A comparison of the catches between May and July sampling showed a significantly higher proportion of large, adult sized fish present in May similar to that found in another rapid run-off river of the Tanana River drainage, the Goodpaster River. In addition, the catch of the two samples, 2,631 fish in May and 3,355 fish in July, when judged by effort (one pass through the area in May versus two passes in July), suggests greater abundance of fish in May. However, an in-season estimate of abundance in the study area during May would likely be problematic due to bias from post-spawning movements occurring during the experiment. A multi-year abundance experiment would probably be more appropriate provided that fish home to this area for spawning each year. Although not entirely conclusive, a number of authors have either presented data or citations that strongly support homing behavior (Tack 1980; Falk et al. 1982; Ridder 1991; Northcote 1993). Recent research in the Goodpaster River suggests not only homing to spawning area but also to specific site. Fifty-three to 60% of Arctic grayling tagged during the spawn and recaptured in the lower 52 km of the Goodpaster River were recaptured within 1.6 km of the release site and 76% to 82% within 8 km of the release site (Ridder *Unpublished*). Forty-one percent of fish recaptured two years after release were recaptured within 1.6 km of the release site (79% were within 8 km). This fidelity to spawning area or site should allow the use of multi-year abundance estimators to assess the Arctic grayling spawning population of the Chena River as long as sample timing is held constant. One advantage of spring sampling is the easily defined and environmentally precise timing, ice-out, of the experiment.

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APPENDIX A

Data File Listing

Appendix A1.-Data files^a used to estimate parameters of the Arctic grayling population in the Chena River in 1998.

Data File	Description
U000201L021998.DTA	Population and marking data (first event) for Arctic grayling captured in the Lower Chena section of the Chena River (river kilometer 0 to 72) 6 through 10 July 1998.
U000202L021998.DTA	Population and marking data (second event) for Arctic grayling captured I the Lower Chena section of the Chena River (river kilometer 0 to 72) 13 through 16 July 1998.
U000105L011998.DTA	Population and marking data (first event) for Arctic grayling captured in the Upper Chena section of the Chena River (river kilometer 72 to 152) 6 through 10 July 1998.
U000106L011998.DTA	Population and recapture data (second event) for Arctic grayling captured in the Upper Chena section of the Chena River (river kilometer 72 to 152) 13 through 16 July 1998.

^a Data files have been archived at, and are available from the Alaska Dept Fish and Game, Sport Fish, Policy and Technical Services, 333 Raspberry Road, Anchorage, Alaska 99518-1599.